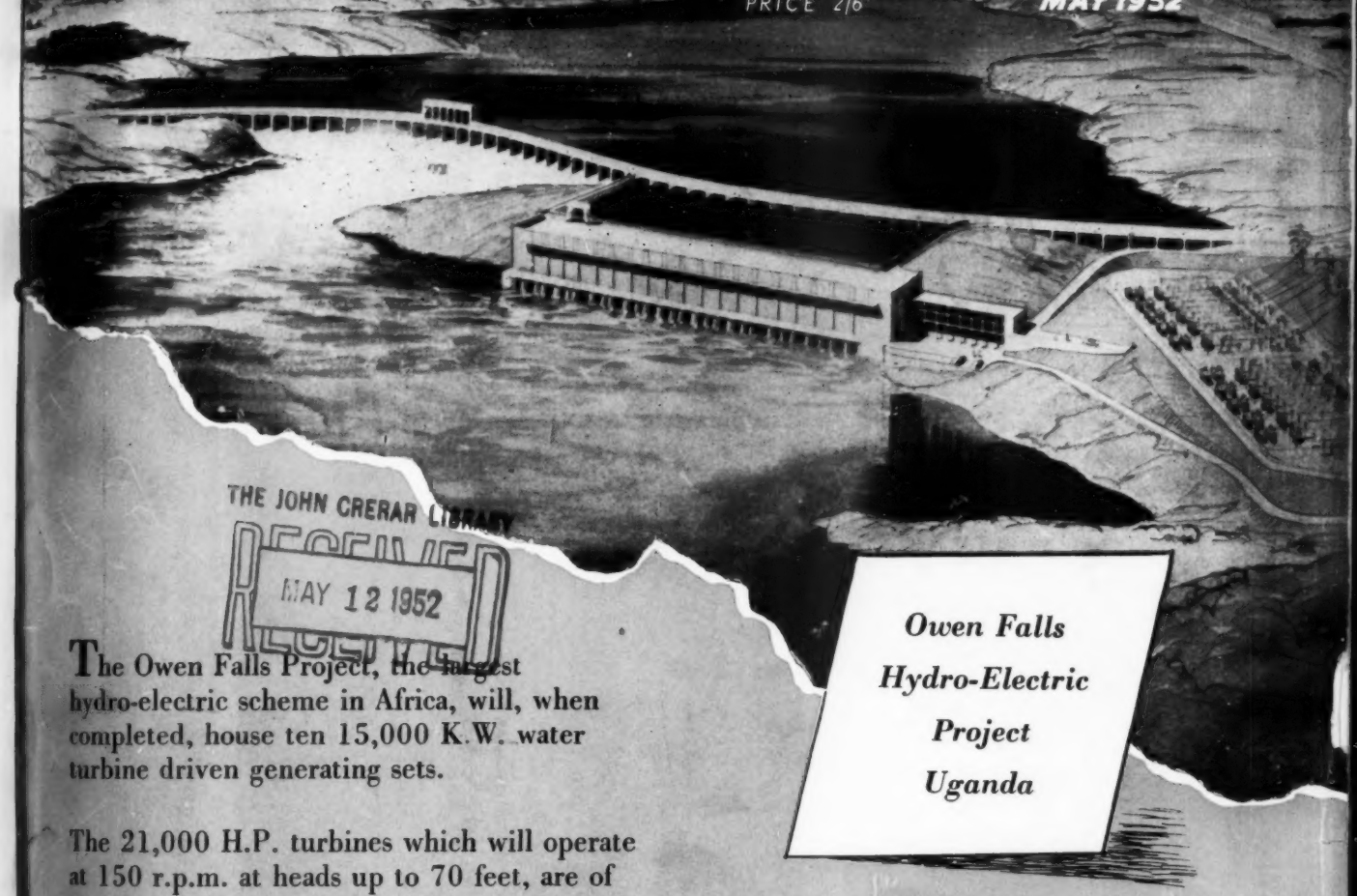
627

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 MAY 1952



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Owen Falls Hydro-Electric Project Uganda

The Owen Falls Project, the largest hydro-electric scheme in Africa, will, when completed, house ten 15,000 K.W. water turbine driven generating sets.

The 21,000 H.P. turbines which will operate at 150 r.p.m. at heads up to 70 feet, are of the Kaplan type with steel plate spirals. Each runner has five cast stainless steel blades and the nominal runner diameter is 13 feet.

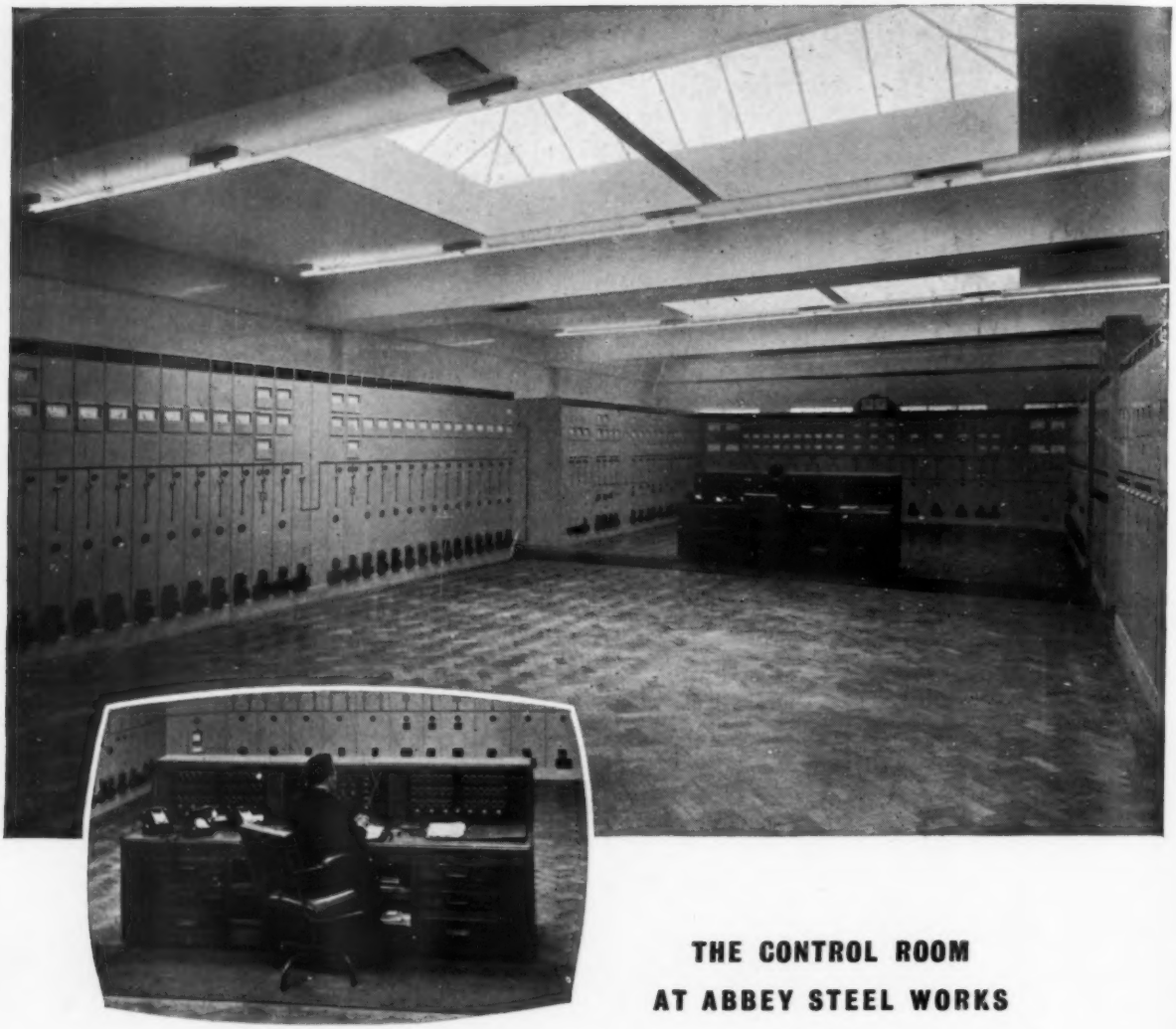
At present six turbines have been ordered, the first of these already being in course of erection on site.

Boving
& COMPANY LIMITED

WATER POWER ENGINEERS

Head Office: 56, KINGSWAY, LONDON, W.C.2, ENGLAND

AUSTRALIA : NEW ZEALAND : INDIA : PAKISTAN



THE CONTROL ROOM
AT ABBEY STEEL WORKS

The control room at Abbey Works, with Reyrolle switchboards for the remotely controlled switchgear in the Works, is a good example of an industrial installation. The instruments have clean, open and readable scales with well defined pointers. The control switches are simple to operate. The system diagram with its mimic semaphores reproduces the switching conditions faithfully.
All apparatus not required for control purposes is dissociated from the panels and the colour scheme both for the panels and the control room is carefully selected to create a pleasing and restful atmosphere.

If you want to talk switchgear ···talk to Reyrolle

A. Reyrolle & Company Ltd., Hebburn, Co. Durham.

CRC 21 S

'ENGLISH ELECTRIC'

hydro-electric plant

Harnessing the World's Water Power

The ENGLISH ELECTRIC Company has specialised in the development of water power projects for many years and has installed hydro-electric plant in countries throughout the world.

In 1951 alone, over 350,000 kW of 'ENGLISH ELECTRIC' plant has been commissioned, and work is in hand for some of the largest hydro installations in the world.

The Company specialises in the production of complete turbine generator units for installations of any head and output, together with all the necessary transformers and switchgear.

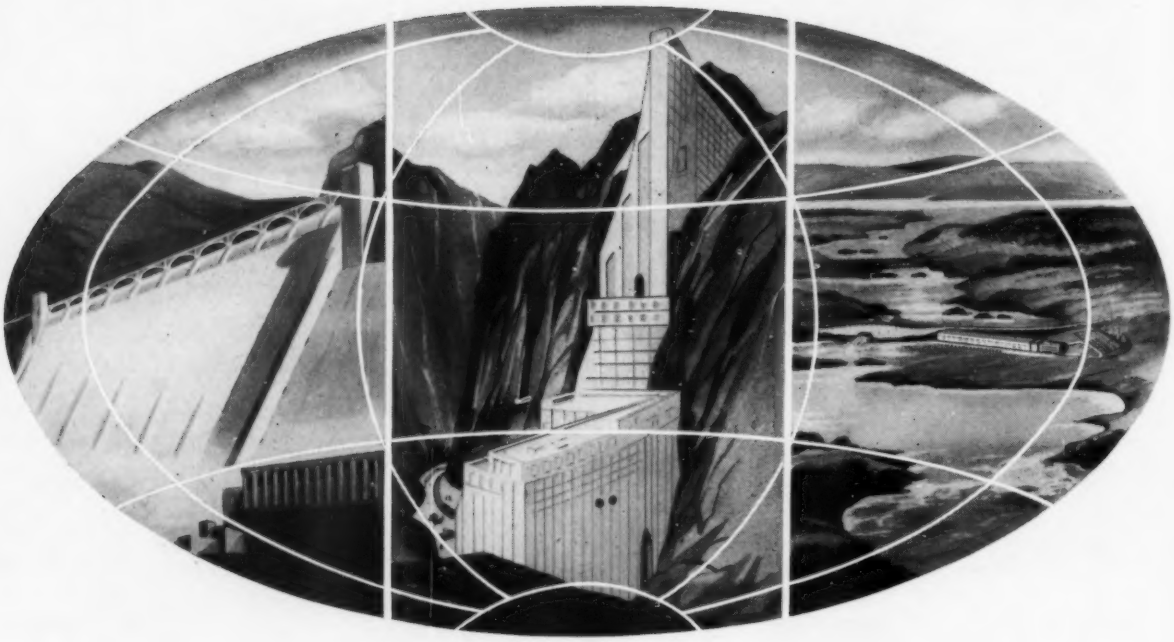
THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Hydro-Electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

H.E.5

PEGSON
PLANT



For Hydro-Electric and Irrigation projects of International repute Pegson Plant has been selected because of its outstanding performance and reliability in operation.

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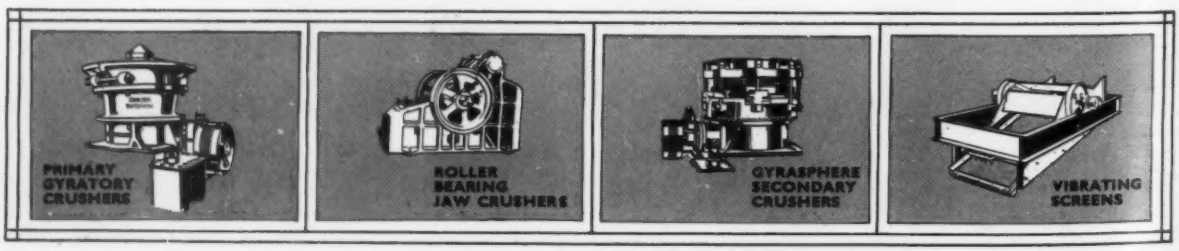
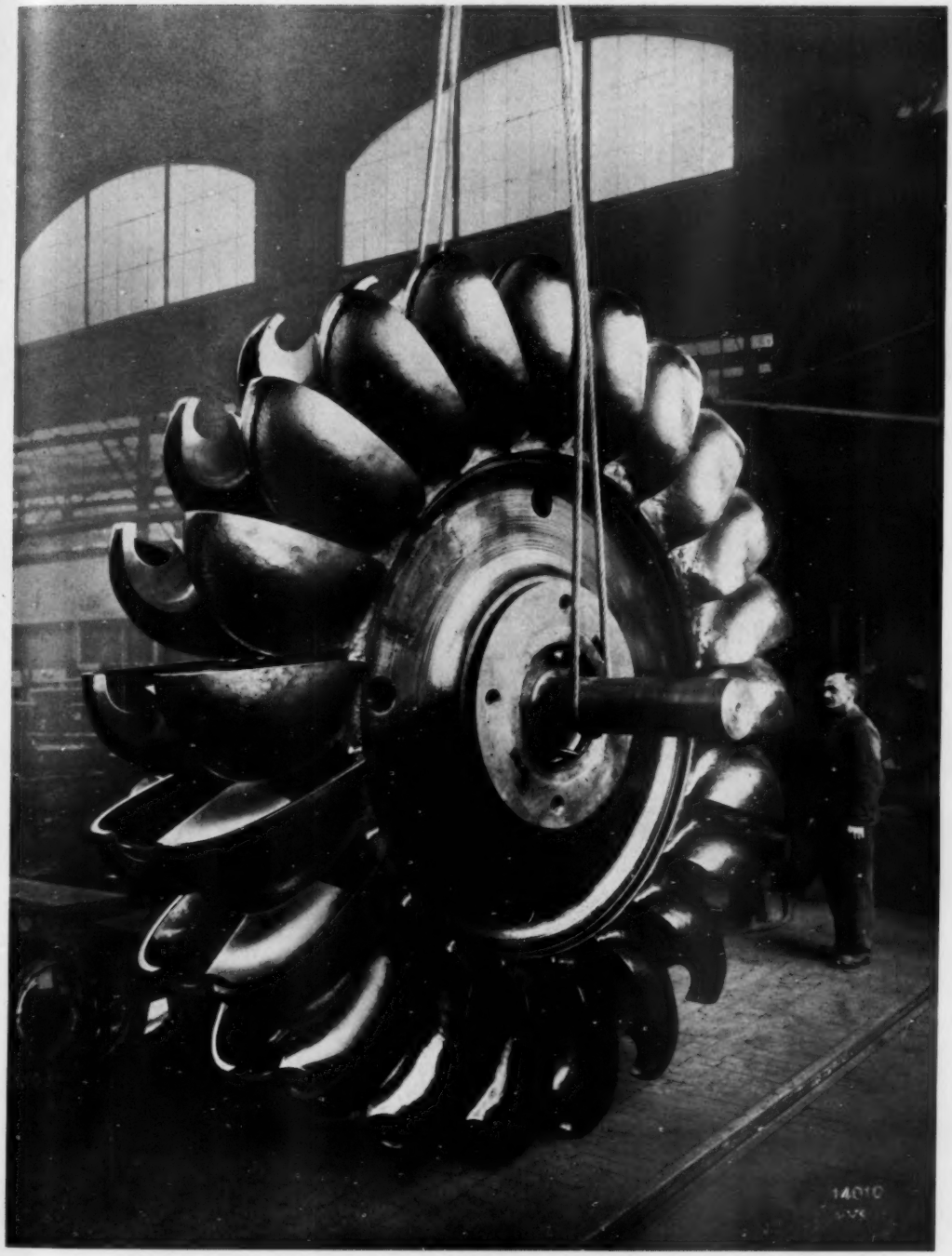
WORKS: COALVILLE, LEICESTERSHIRE. TELEPHONES: ABBEY 2373. COALVILLE 234
A COMPANY OF THE MELLOR BROMLEY GROUP





Impulse type runner cast in one piece and developing about 66,000 h.p. Supplied to the Kraftwerke Oberhasli A.G. for their Innertkirchen Power Station. The total output of the turbines ordered from Escher Wyss by these clients for the Innertkirchen, Handeck and Grimsel power plants exceeds 500,000 h.p.

We further specialize in Kaplan and Francis turbines up to the largest outputs and heads, as also in large storage pumps and other hydraulic equipment.

Our experience in manufacture and in installation work all over the world is at your disposal.

ESCHER WYSS LTD., ZURICH (SWITZERLAND)

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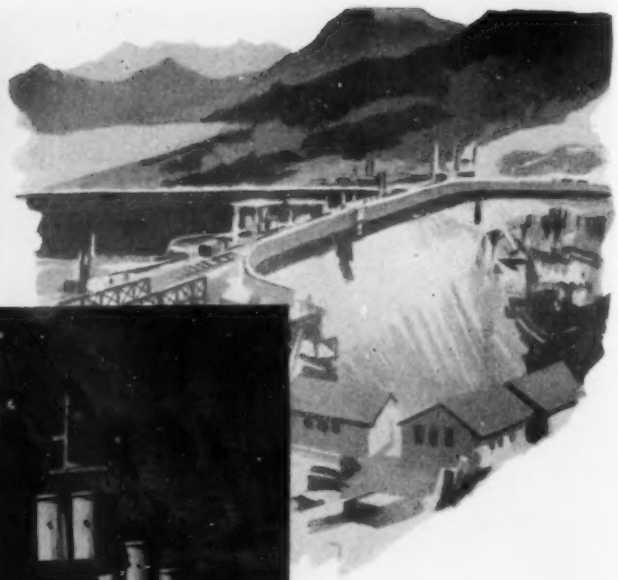

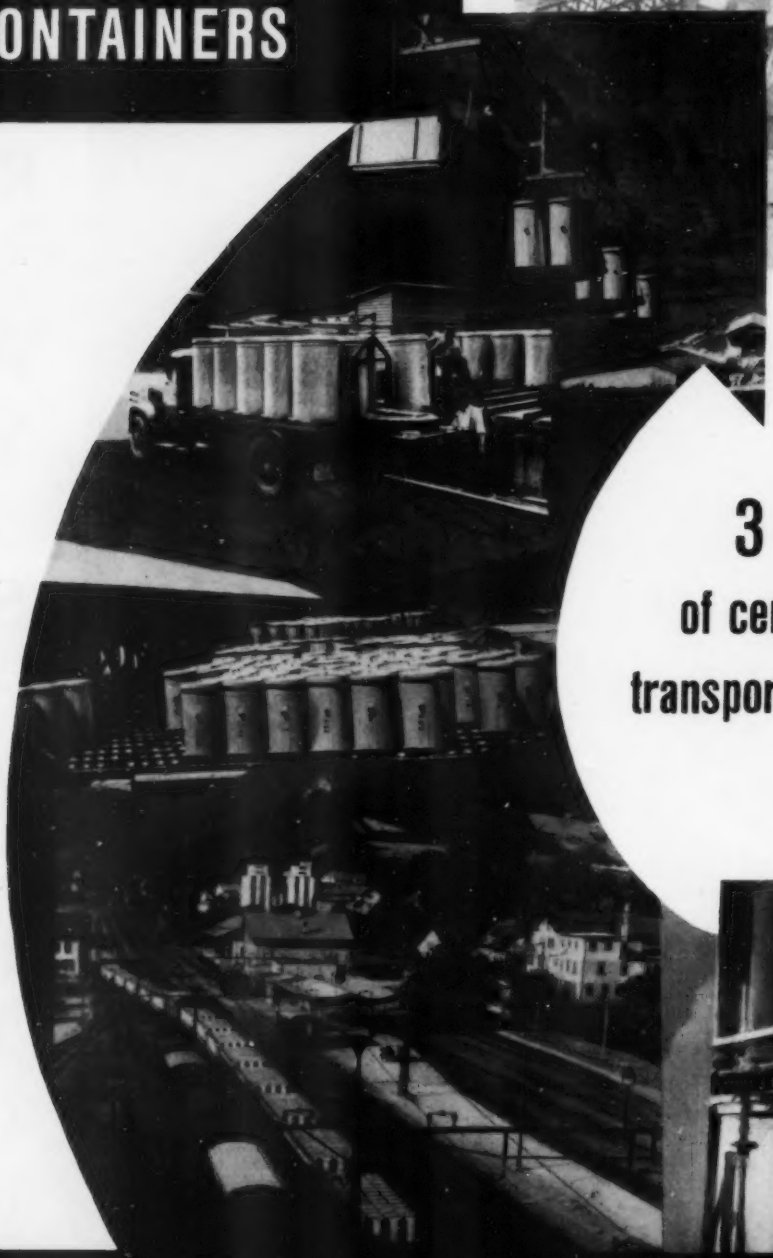

3 million tons
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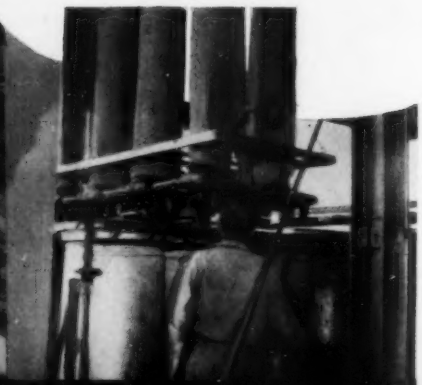

For all information, address:
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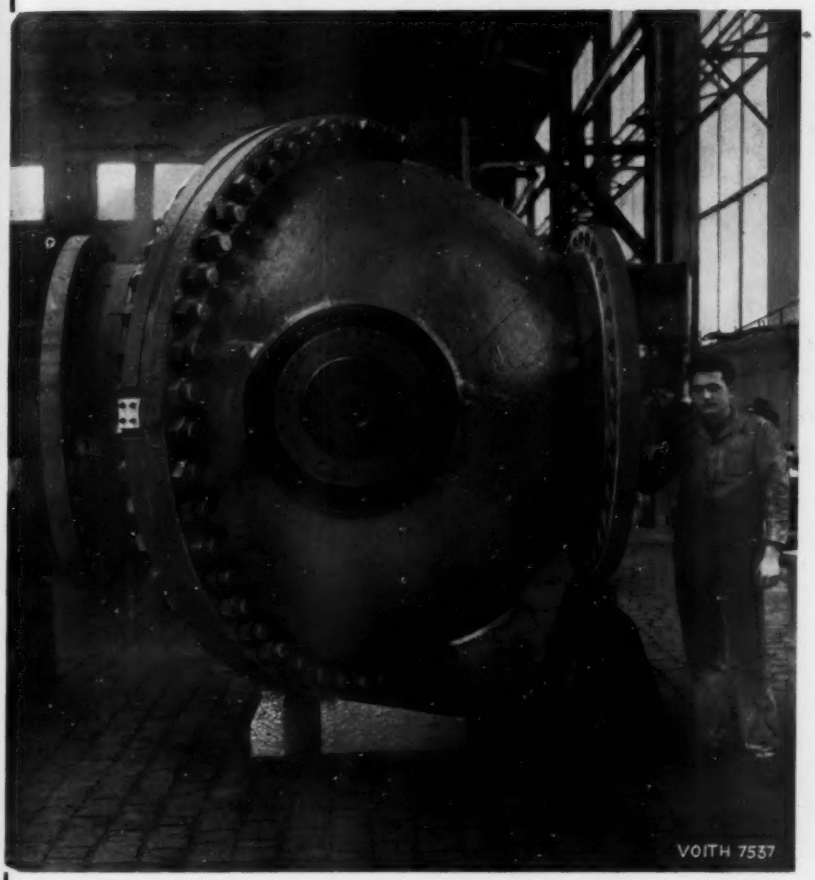
(SWITZERLAND)

Voith-Penstock Shut-off Valves



Workshop assembly of a spherical valve, inside diameter 1,300 mm, with hydraulic drive. The casing of the spherical valve is diagonally split.

We have supplied:

Spherical Valves inside diameters up to 2,200 mm, maximum water pressures up to 1,010 m water column.

Needle Valves inside diameters up to 2,800 mm, maximum water pressures up to 600 m water column.

Butterfly Valves inside diameters up to 5,300 mm at 70 m water column.

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Heidenheim (Brenz), Germany

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for water power

HIGH HEADS

MEDIUM HEADS

PELTON WHEEL

TURGO IMPULSE WHEEL

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With the great and growing demand for electric power in most countries the question of developing this power from water becomes ever more important.

Water turbines and governors, designed and manufactured by us, are exported to all parts of the world. They are installed in many types of plant including H.E. power stations, mills, farms, etc., and range from 1 to 10,000 horsepower.

Write for our brochure M.5/1951

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WATER TURBINE AND PUMP MANUFACTURERS

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BRUCE PEEBLES

TRANSFORMERS

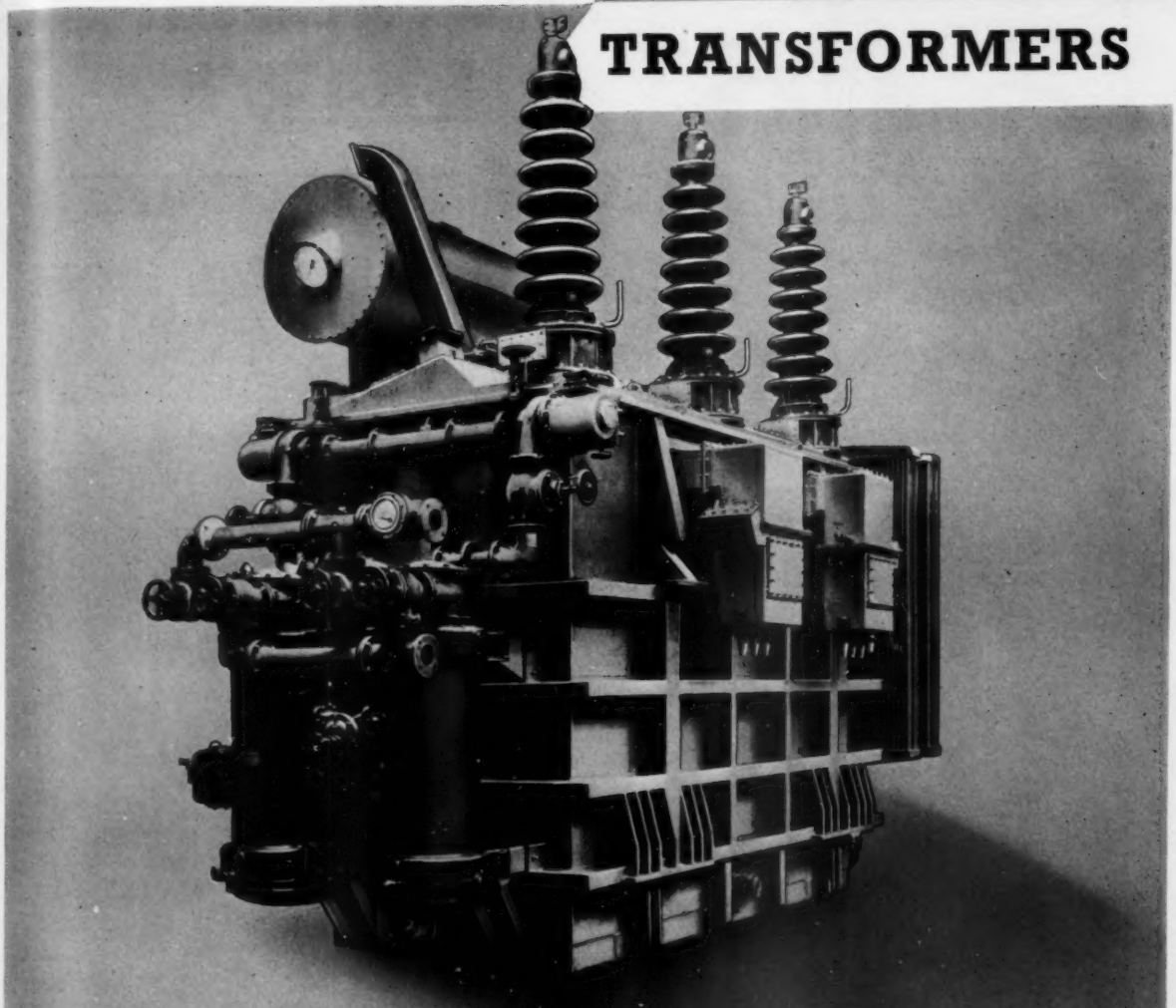

Illustration shows a 20,000 kVA, 132,000/11,000-volt water-cooled transformer typical of many supplied for Scottish hydro-electric schemes.

PEEBLES TRANSFORMERS running into millions of kVA in units up to 75,000 kVA have been supplied for use all over the world, and larger equipments for the British Super-Grid are now on order.

In practically every country you will find Bruce Peebles Transformers ranging from small pole mounting type to large power units.

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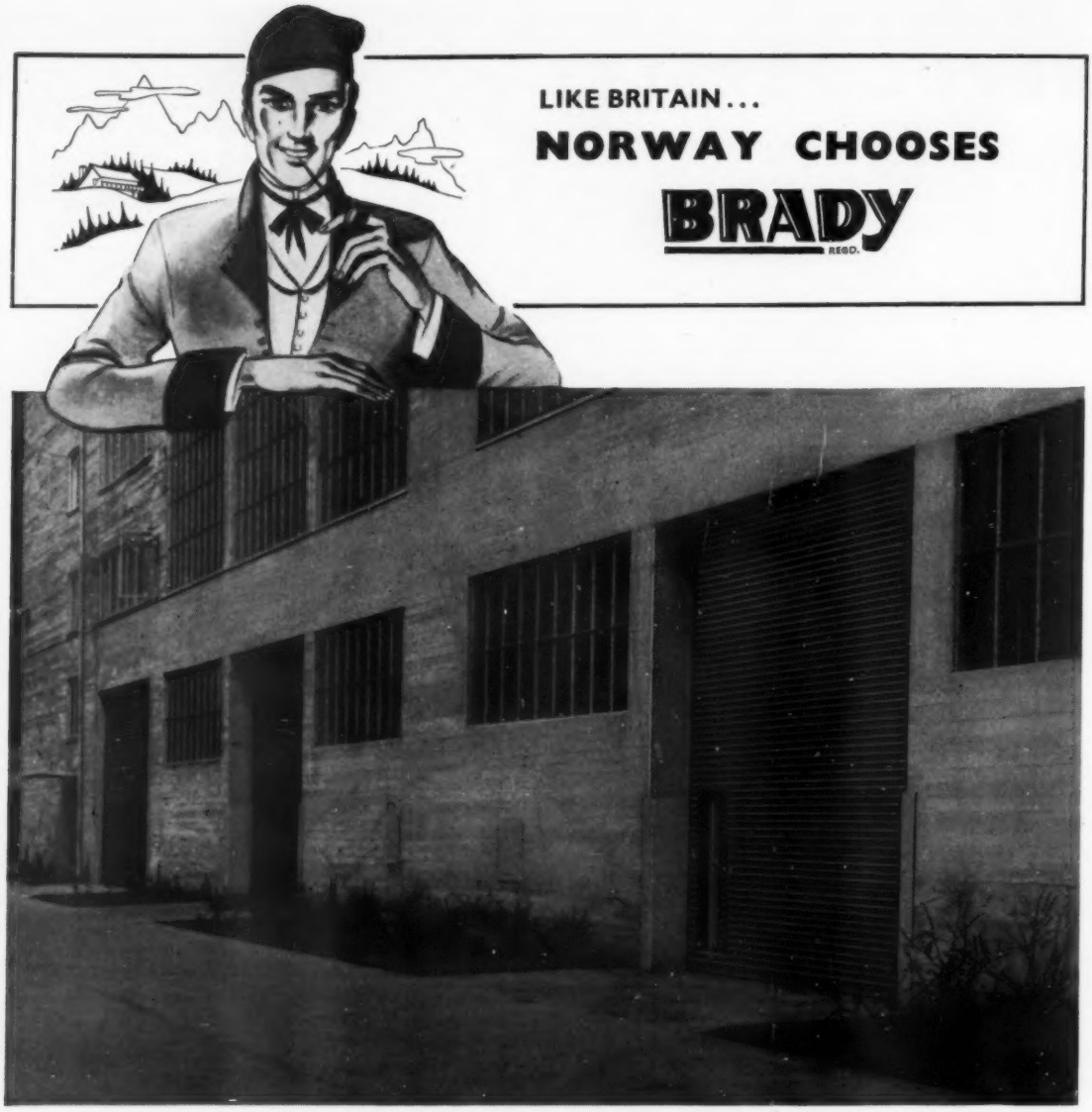

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ON HYDRO-ELECTRIC WORK

A VIEW ON LOCH LOMOND SIDE

BUTTERS CRANES

have served with their traditional reliability in most corners of the world — the ubiquitous Butters Derrick and the more specialised Butters Monotower which was designed specially for such work. Illustration shows a 20 ton and a 7 ton electric derrick on the Loch Sloy Scheme.

BUTTERS BROS. & CO. LTD.

Head Office & Works: **MACLELLAN ST., GLASGOW, S.1 and at LONDON, BIRMINGHAM & NEWCASTLE**

Conways are prodigious tunnellers too!

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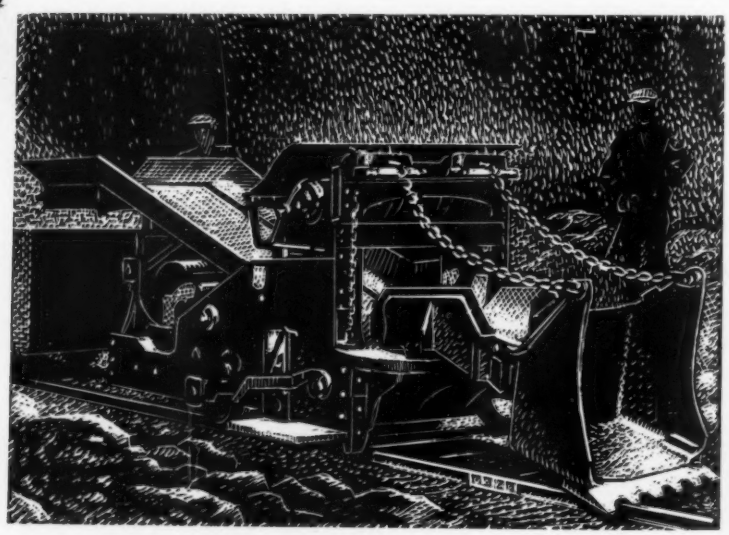
With its faster loading and bigger yardage per man shift, the Conway makes any tunnelling project an economic operation. One man controls all operating movements. *One* man and *one* power unit handle tramming, rooting, swinging and hoisting, operating them together or singly. No hand shovelling is needed; a clean heading is assured by an arcing radius of 55°.

Working in partnership with the Conway clutch operated endless belt conveyor, the loader will keep trucks or conveyors moving at the average rate of 200 tons an hour; fast enough to fit into the speediest drilling, firing cycle. *Let us give you a demonstration. Brochure free on request.*



BRITISH CONWAY LOADERS *World's Champion Tunnellers*

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"Shell-Type"

OF 75 000 kVA, INTENDED FOR THE BELGIAN CENTERS OF INTERCONNECTION FOR NETWORKS OF 150/70 kV.

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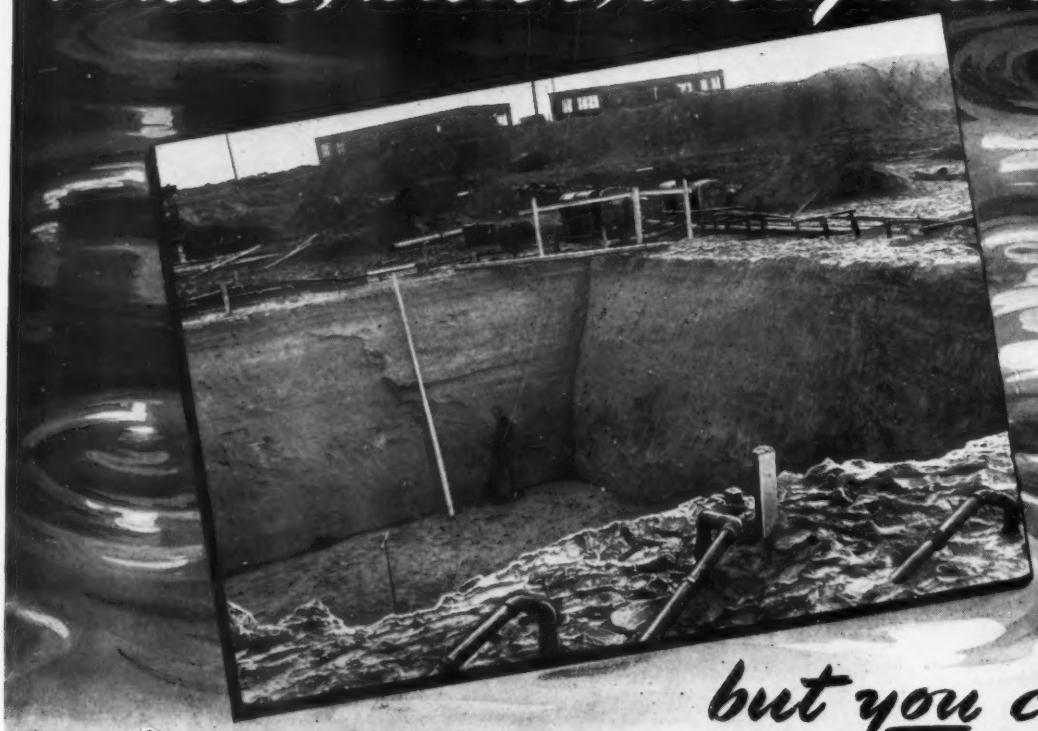
Water, water, everywhere!



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Consulting Engineers and Civil Engineering Contractors cannot be sure that the problems of foundation work in water-bearing sub-soils are being tackled with the utmost efficiency until they have at least investigated the Blaw Knox Wellpoint Dewatering System. In running sand where subsidences and "boiling" occur when timbering or sheet piling is used, and also in varied stratum, Blaw Knox Wellpoint Dewatering has proved itself to be the SURE method to make "every job a dry job", overcoming ground water difficulties which can so easily cause serious financial loss.

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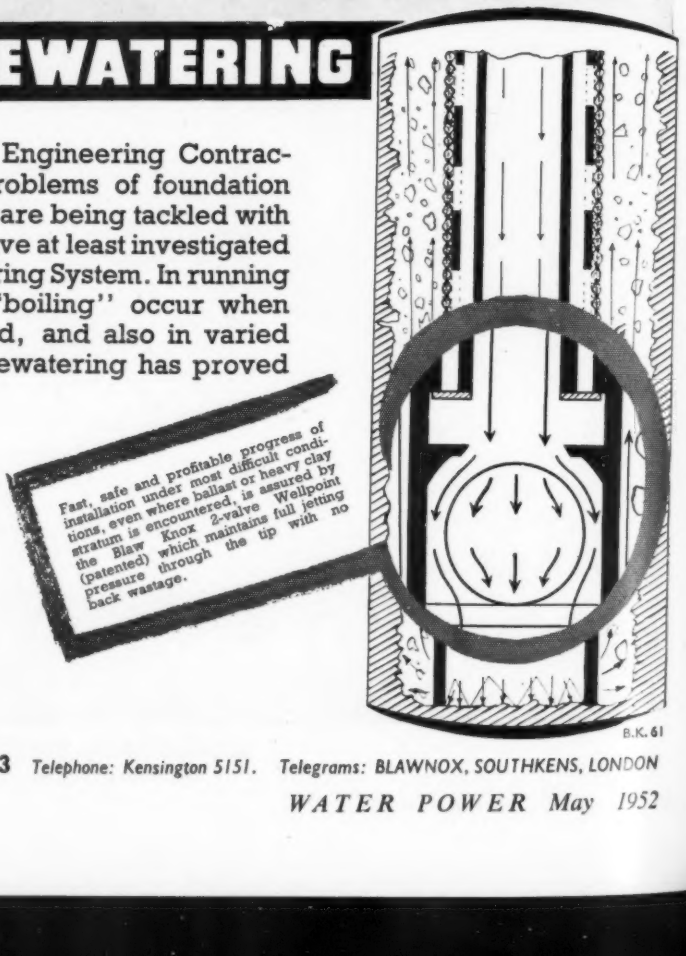
Fast, safe and profitable progress of installation under most difficult conditions, even where ballast or heavy clay stratum is encountered, is assured by the Blaw Knox 2-valve Wellpoint (patented) which maintains full jetting pressure through the tip with no back wastage.
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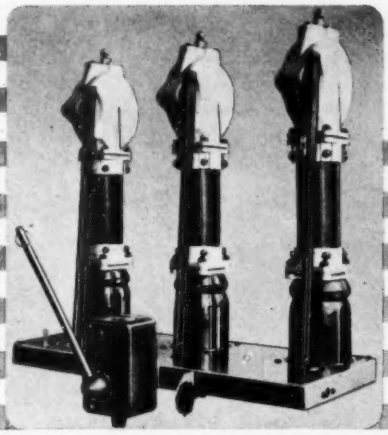

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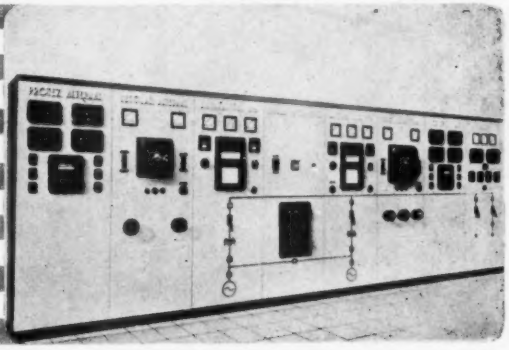

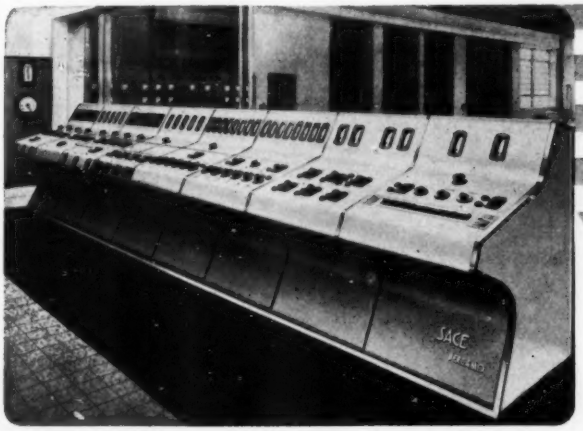

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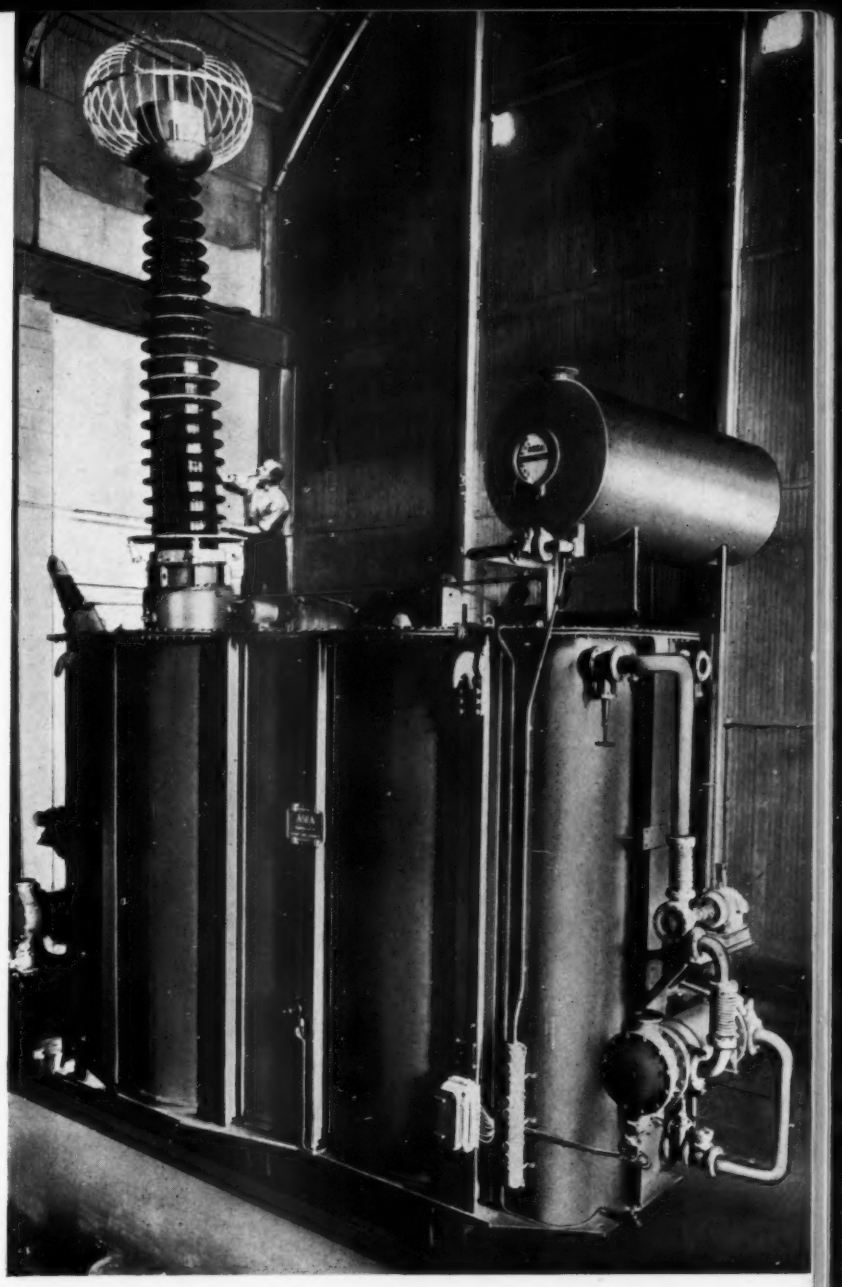
— a series of world records in electrical power engineering



The first 220 kV power transmission system in Europe was commissioned in Sweden in 1936 and employed transformers and equipment manufactured by Asea. This transmission system from the north to the central and southern parts of Sweden which carries about 1,500,000 kW has now been expanded to 6 parallel lines having a combined length of about 3,000 km (1,800 miles).

In 1946 it was decided to utilize the power of the largest waterfall in Sweden, Harsprånget, situated north of the Arctic Circle. It was necessary to transmit the power for nearly 1,000 km and after careful investigation it was decided to employ a maximum service voltage of 400 kV. This plant too is being provided with Asea equipment including generators, transformers, high voltage circuit breakers and isolators as well as other equipment.

The extensions in progress at the moment comprise 3 vertical generators each rated at 105,000 kVA, or, in other words, machines of the same order of size as those installed at the American Boulder Dam site.

The transformer deliveries comprise 34 single-phase units for 380,000 V, in sizes ranging from 43,500 to 115,000 kVA and intended to form three-phase banks of up to 345,000 kVA. In physical size some of these transformers will be the largest units ever made. The rating of the largest three-winding transformer bank, expressed as equivalent two-winding rating, amounts to almost 450,000 kVA. Built for a maximum voltage of 220,000 V instead of 400,000 V, using the same core and with the same total weight, their rating would have exceeded 200,000 kVA per unit — another world record added to those previously established by Asea.

Asea's deliveries of high voltage equipment include a number of air-blast breakers for 380 kV, 1,200 A and a rupturing capacity of 8,000,000 kVA as well as isolators and instrument transformers.

To-day as ever Asea stands in the front rank in the development of electrical power engineering. Consult our experts on all problems involving high-voltage power.

VÄSTERÅS **ASEA** SWEDEN

North of Scotland Hydro-electric Scheme

The supply and erection of some ninety miles of 132kV overhead transmission lines, over the wild and rugged Highlands, was recently entrusted to Henley's Contract Department by the North of Scotland Hydro-Electric Board.

Illustration. Hillside view of HENLEY 132kV single circuit towers overlooking Loch Luichart. (Note: The footings of one tower are above the peak of the other which is only 150 ft. distant.)

Consultants: Messrs. Kennedy and Donkin

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ELECTRIC CABLE
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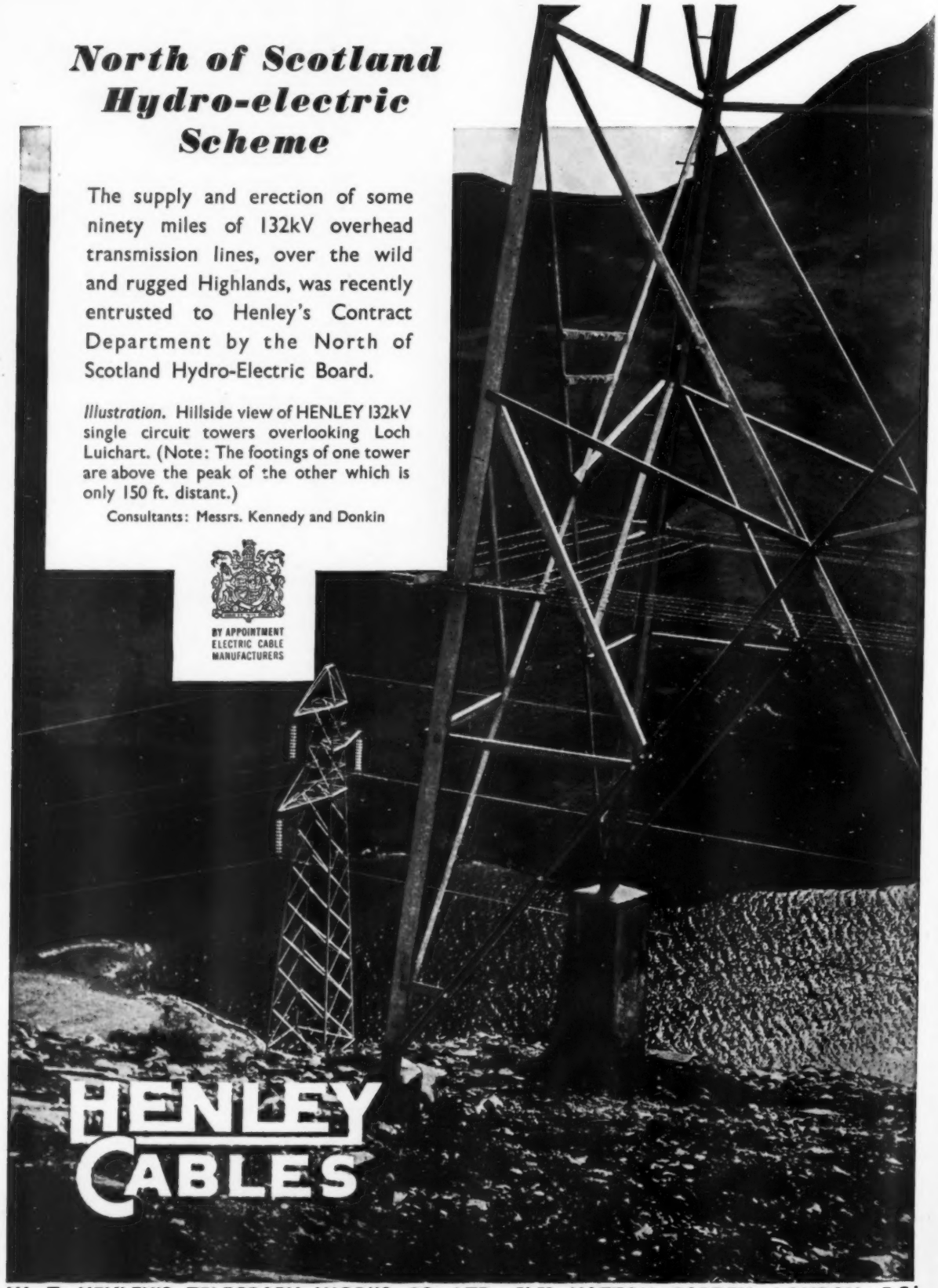

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Vision in Hydraulics

DRAW back the curtain of history—1875—and inventive man, S. Morgan Smith, putting the finishing touches to the model of his first turbine—one of the few machines of its type to prove successful in the early days of hydro development in the United States.

The 77 years which have followed constitute a period of bold and amazing achievement in human progress. And the business which bears his name has kept pace with engineering advancement and is today a testimonial to the intellect, inventive genius and sound vision of the Founder!

If It's Hydraulics~ Put It Up to Us!

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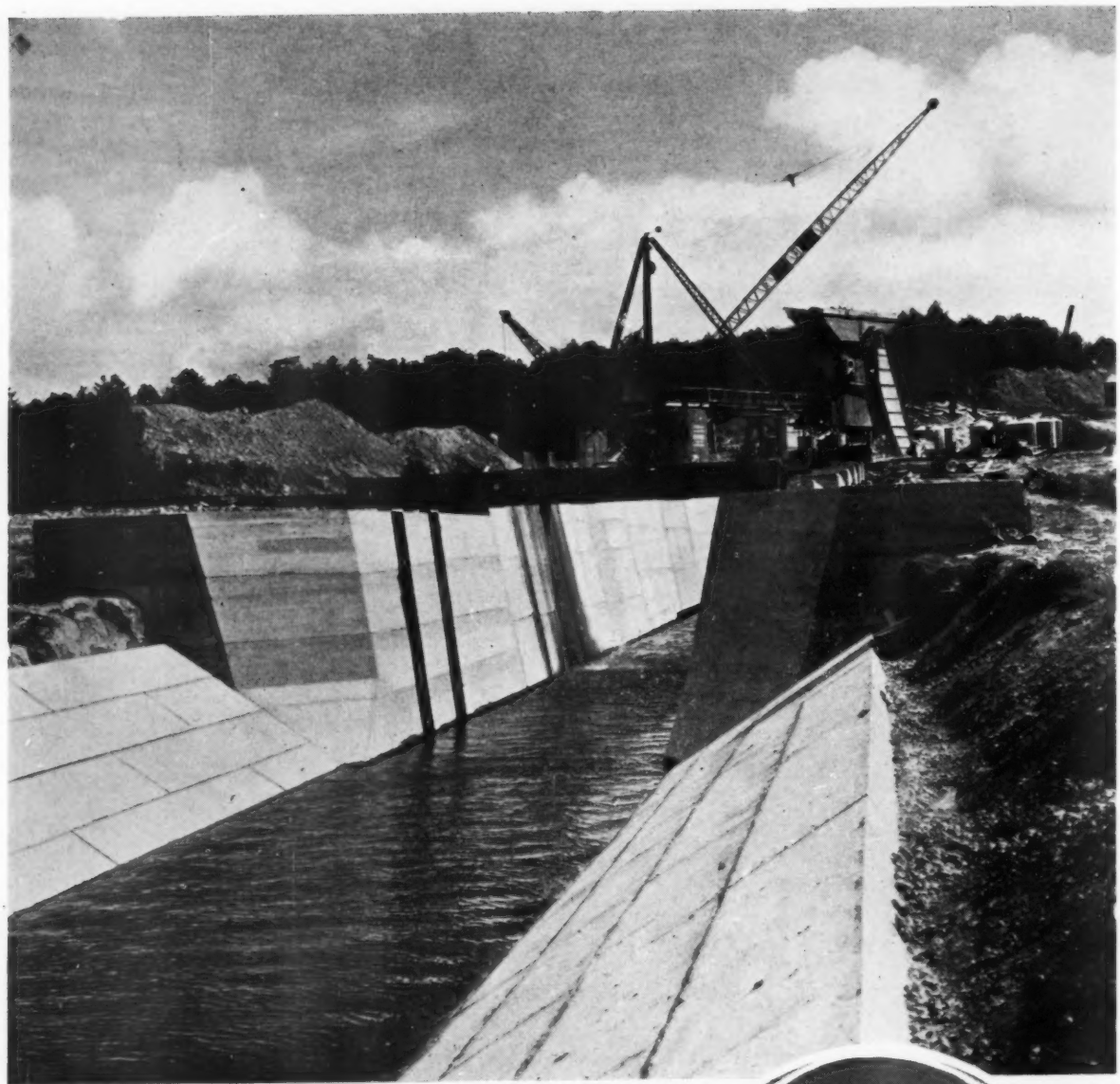

Work on the diversion tunnel and channel at the Weir Wood Reservoir Contract, which is one of the water conservation schemes being carried out by the Company

Consulting Engineers: Herbert Lapworth Partners

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COSTAIN
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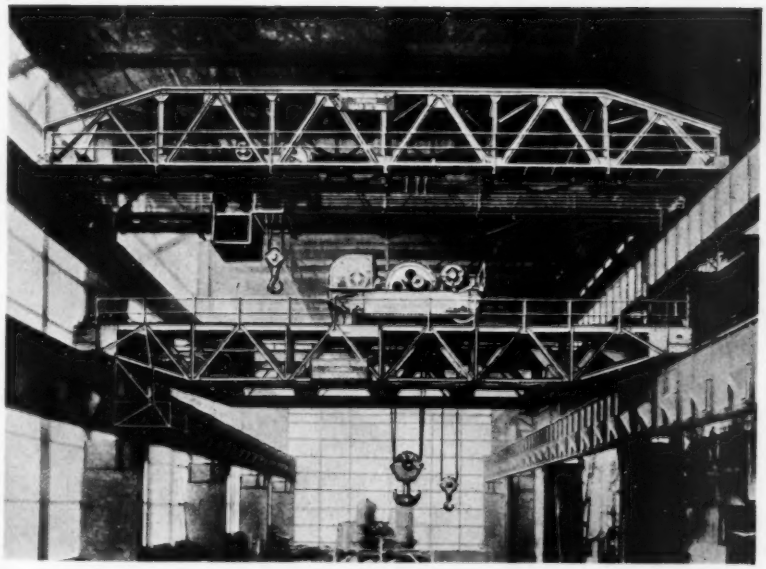
Building & Civil Engineering Contractors

Arrol:

build many cranes. Their name-plate appears on the tallest tower cranes; the largest cranes (of 300 tons capacity) in any forge; the best designed steelworks cranes.

Cranes

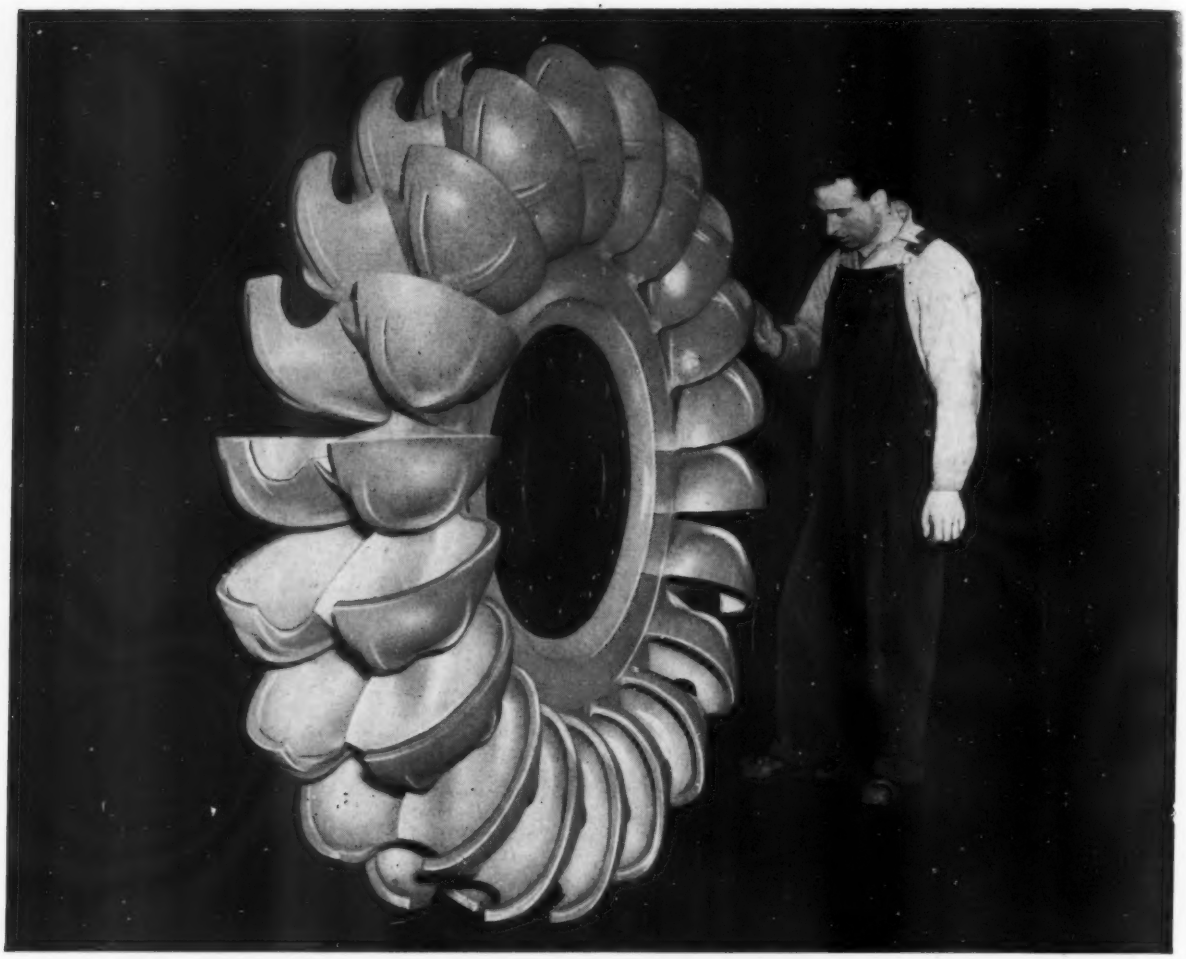


Two Arrol Overhead Electric Travelling Cranes installed in a power station. Capacities are 175 tons and 30 tons, the former being provided with auxiliary hoisting also.

and:

All types of Steel Framed Buildings, Fixed and Opening Bridges, Cranes and Mechanical Engineering Work, Dock Gates, Sliding and Floating Caissons, Compressed Air Locks, Hydraulic Machinery, Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Stations.

SIR WILLIAM ARROL & CO. LTD., GLASGOW



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Your inquiries are invited.

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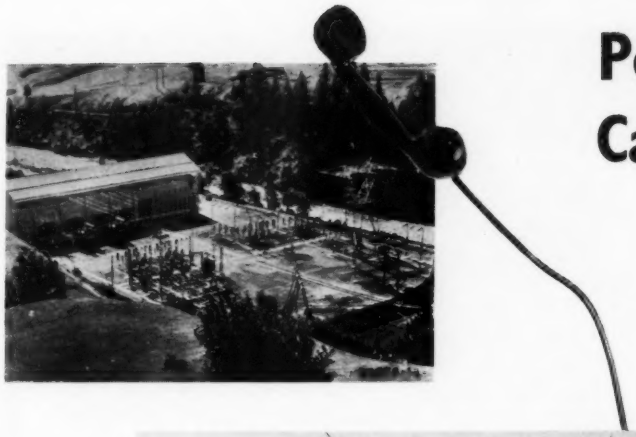
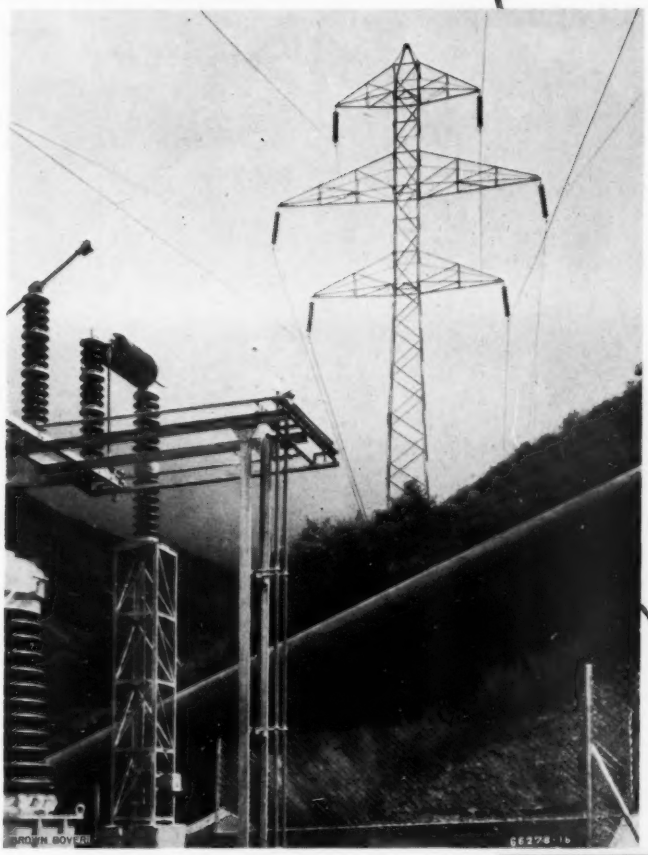
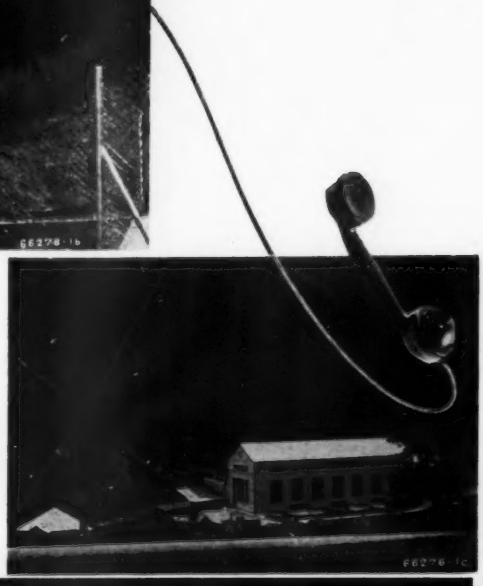
Power-Line Carrier Telephony





Coupling equipment of a carrier telephony transmission at the Mörel power station (Switzerland). 500-A double-wave trap and associated coupling capacitor mounted on a special frame in the outdoor switching station. This carrier link, superimposed on the 150-kV transmission line over the Nufenen Pass, permits telephone communication between the Mörel and Lucendro power stations.



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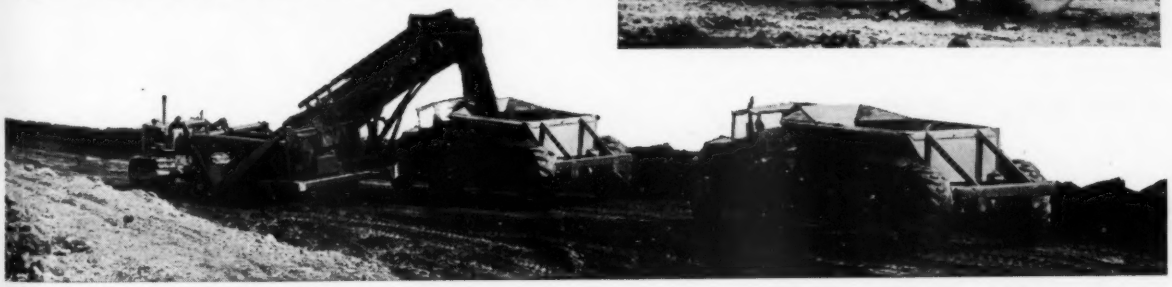

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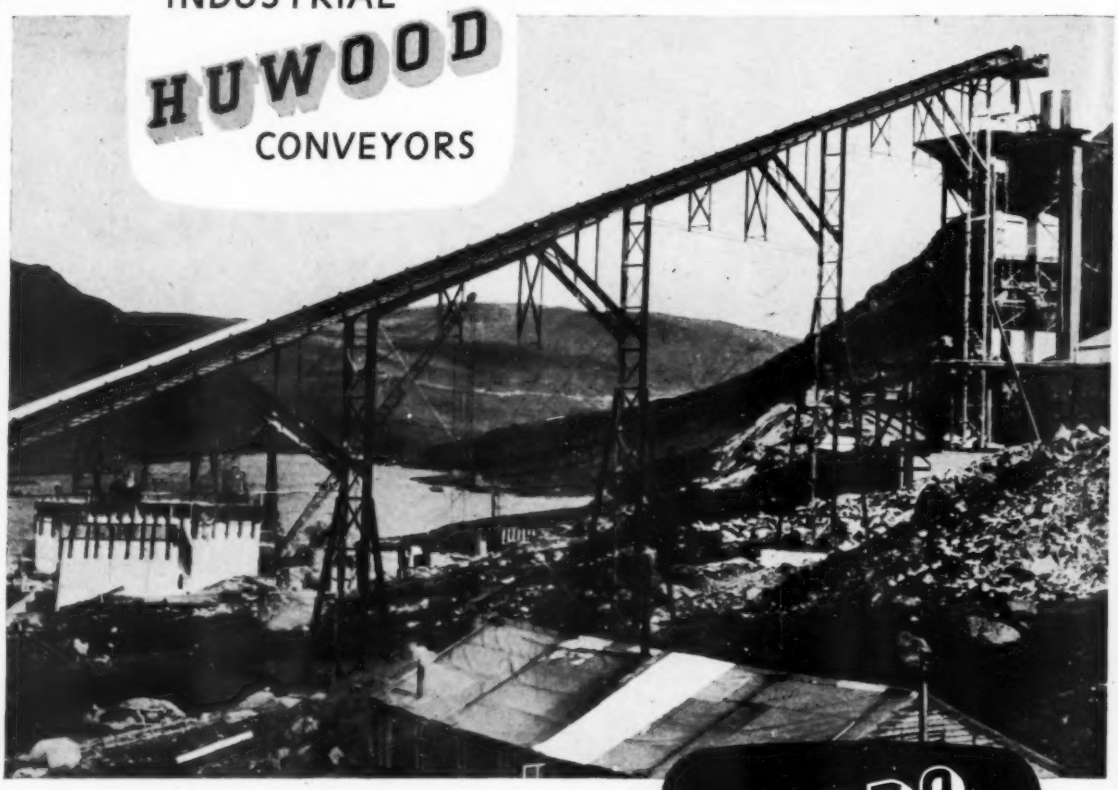

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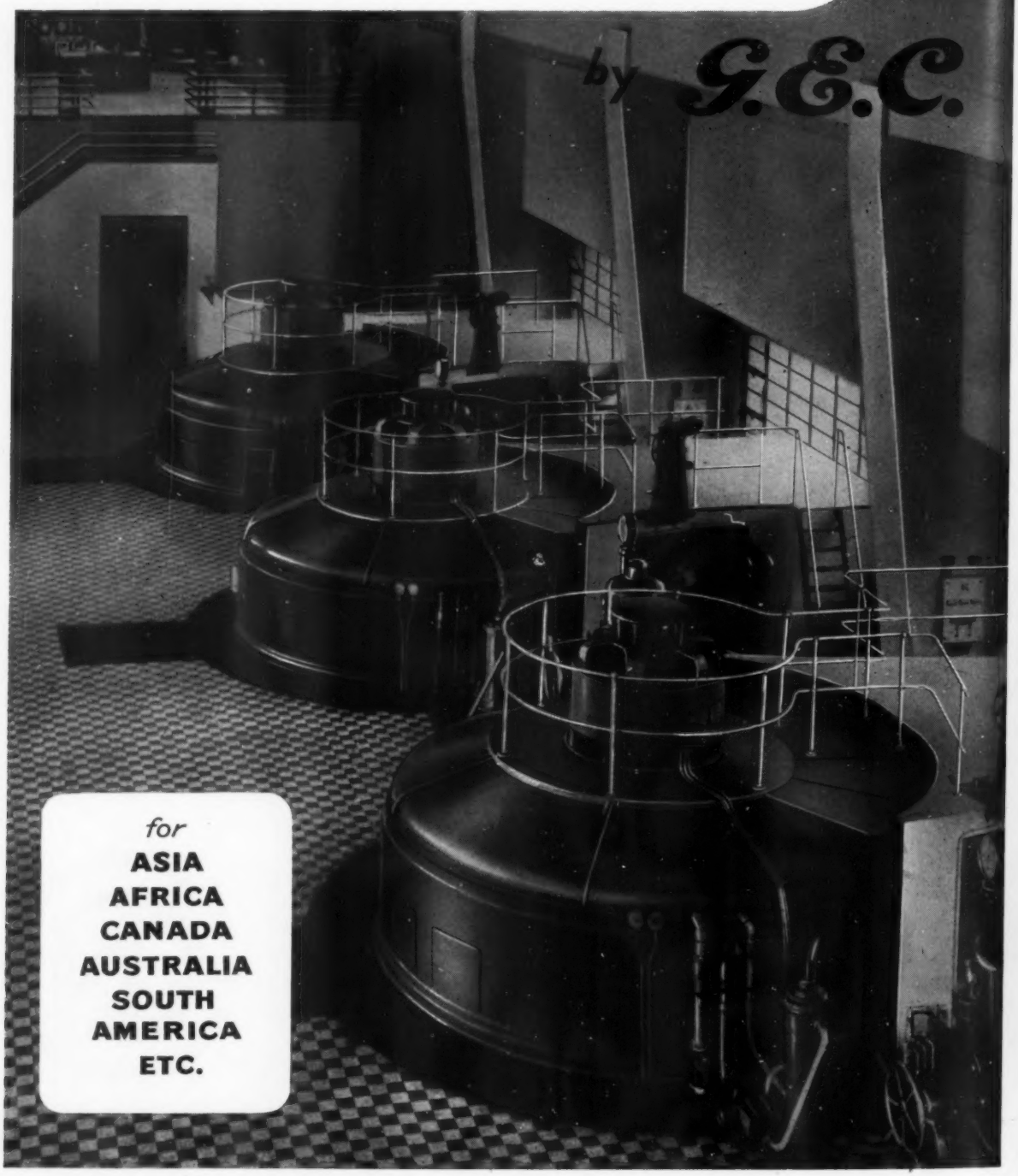

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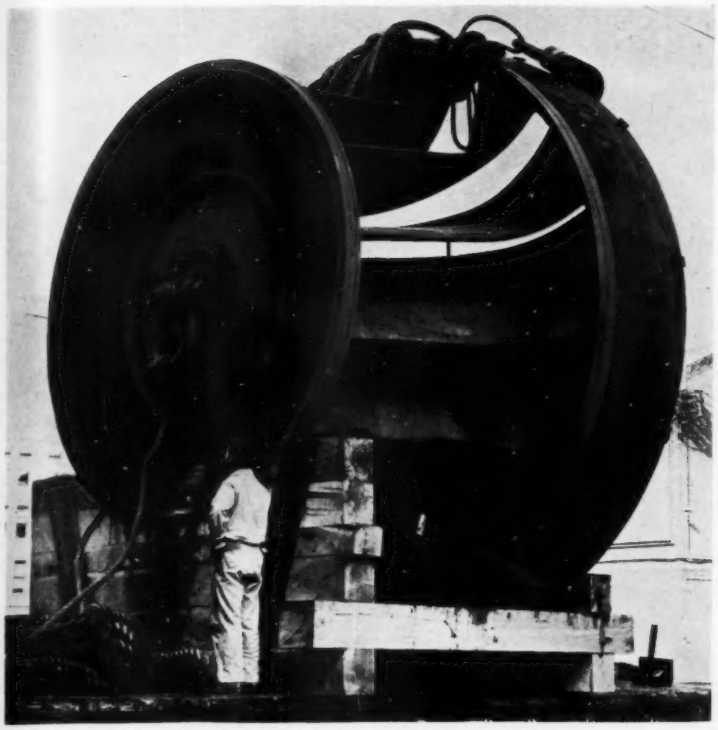

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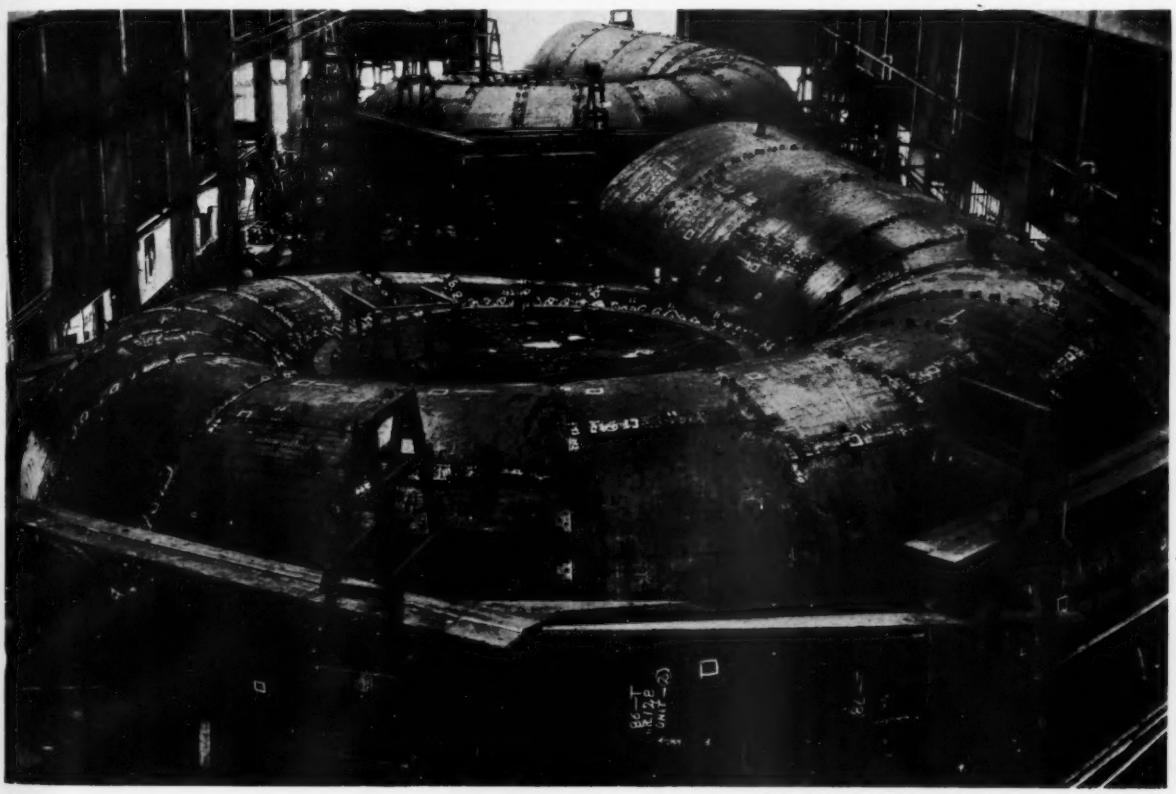

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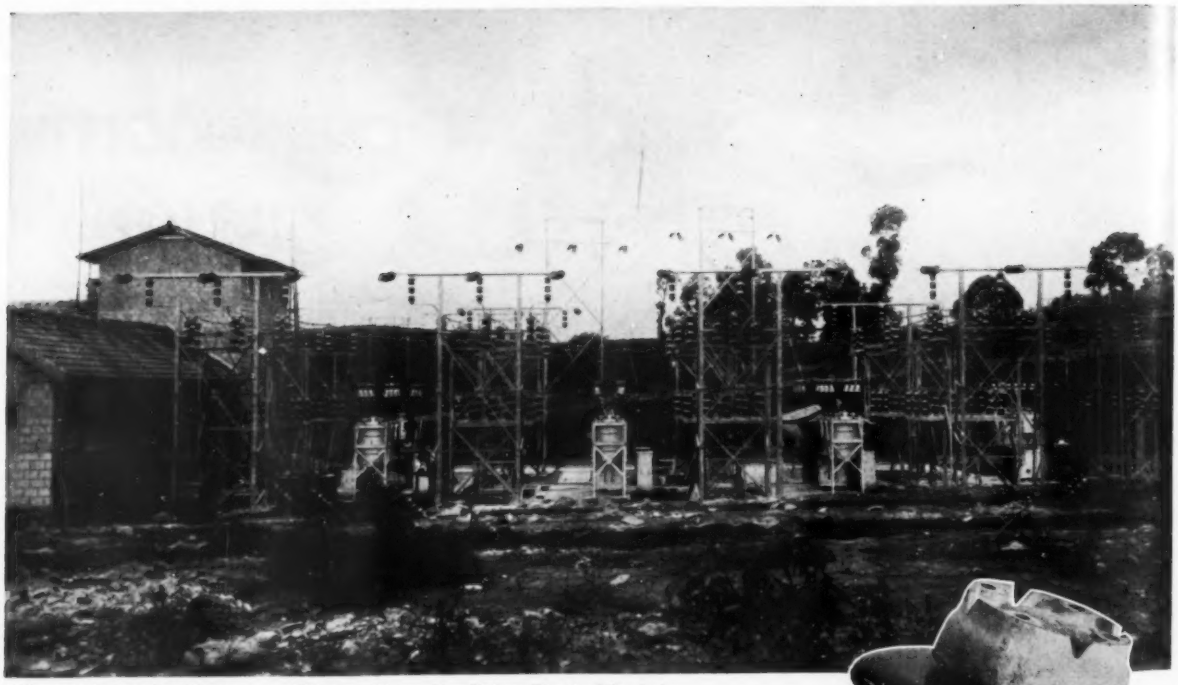

(Photograph reproduced by courtesy of Messrs. Metropolitan Vickers Electrical Co. Ltd.)

The substation at Kothamangalam, Travancore, India, one of the 66kV substations on the Pallivasal project equipped with S.P.P. Post insulators type P.642.

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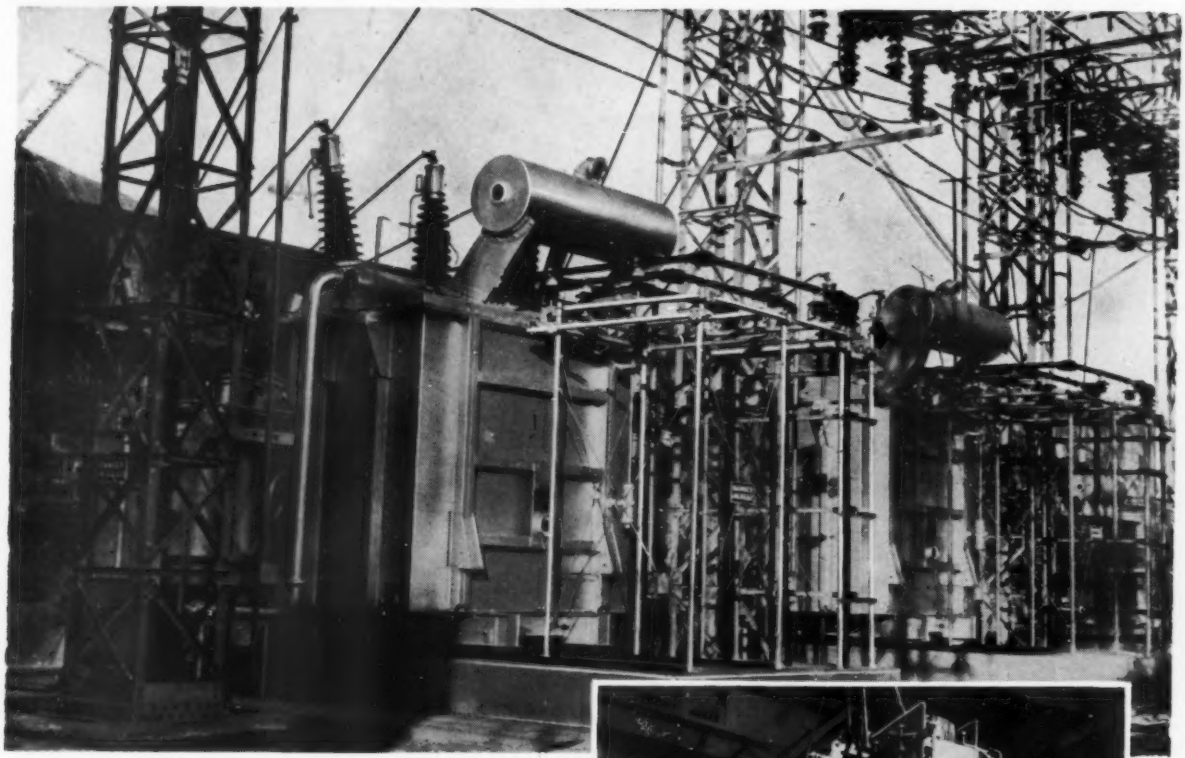

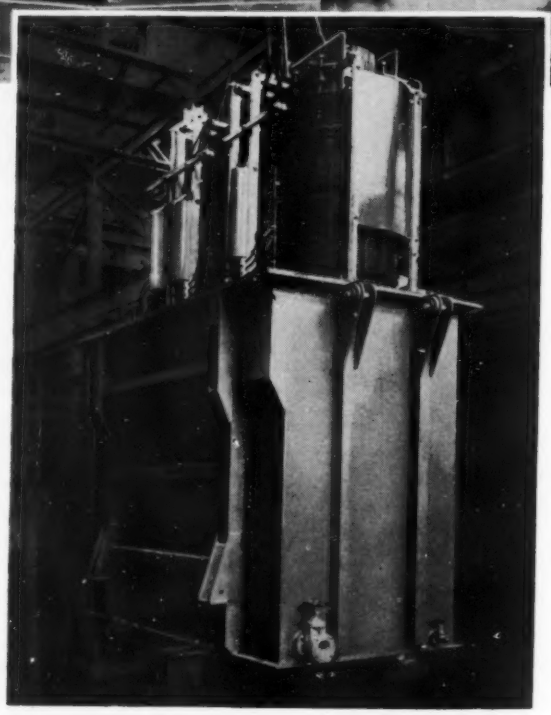

Two of the three 17,500 kVA. 11,000/66,000/110,000 volt step-up transformers, installed at the Mettur Hydro-electric Power Station for the Madras Government.

Core and coils being lowered into tank after final drying-out prior to shipment.

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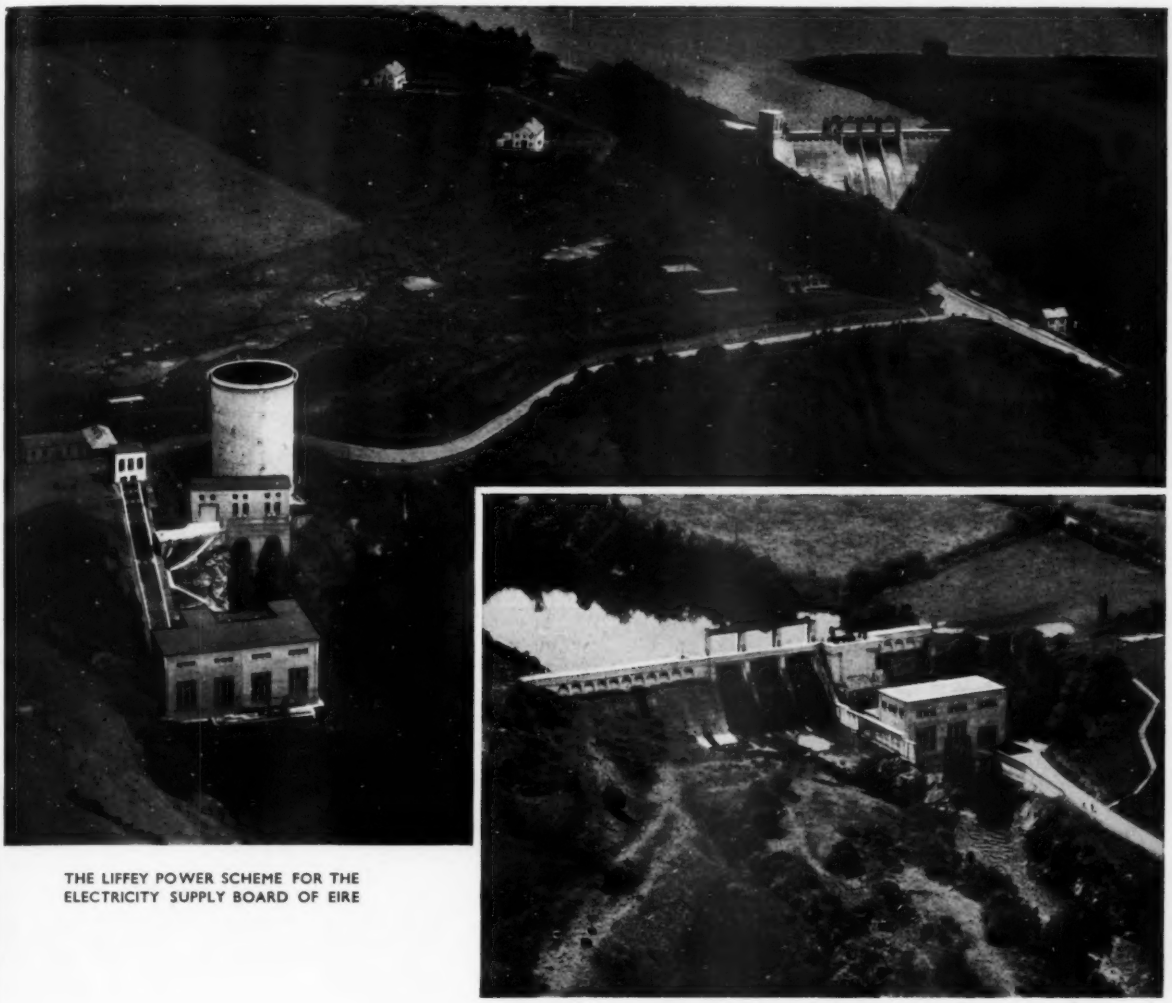

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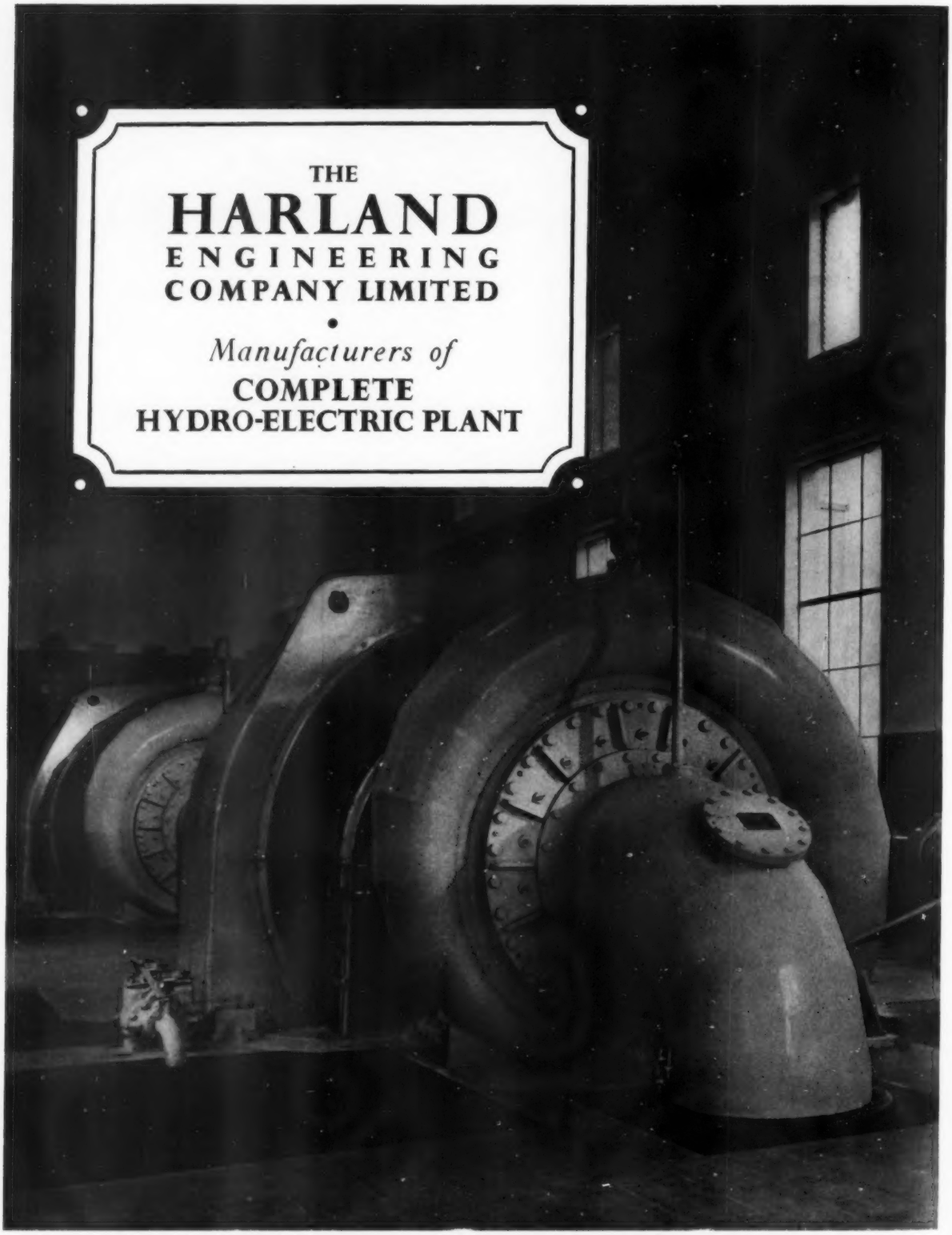

Officially opened on September 26th 1951, the Loch Striven Power Station of the North of Scotland Hydro-Electric Board contains 2 - 4250 B.H.P. "Harland Morgan Smith" Francis Turbines driving 3000 K.W. "Harland" alternators—a fine example of hydraulic and electrical generating plant manufactured under one roof and erected at site by Harland specialist engineers.

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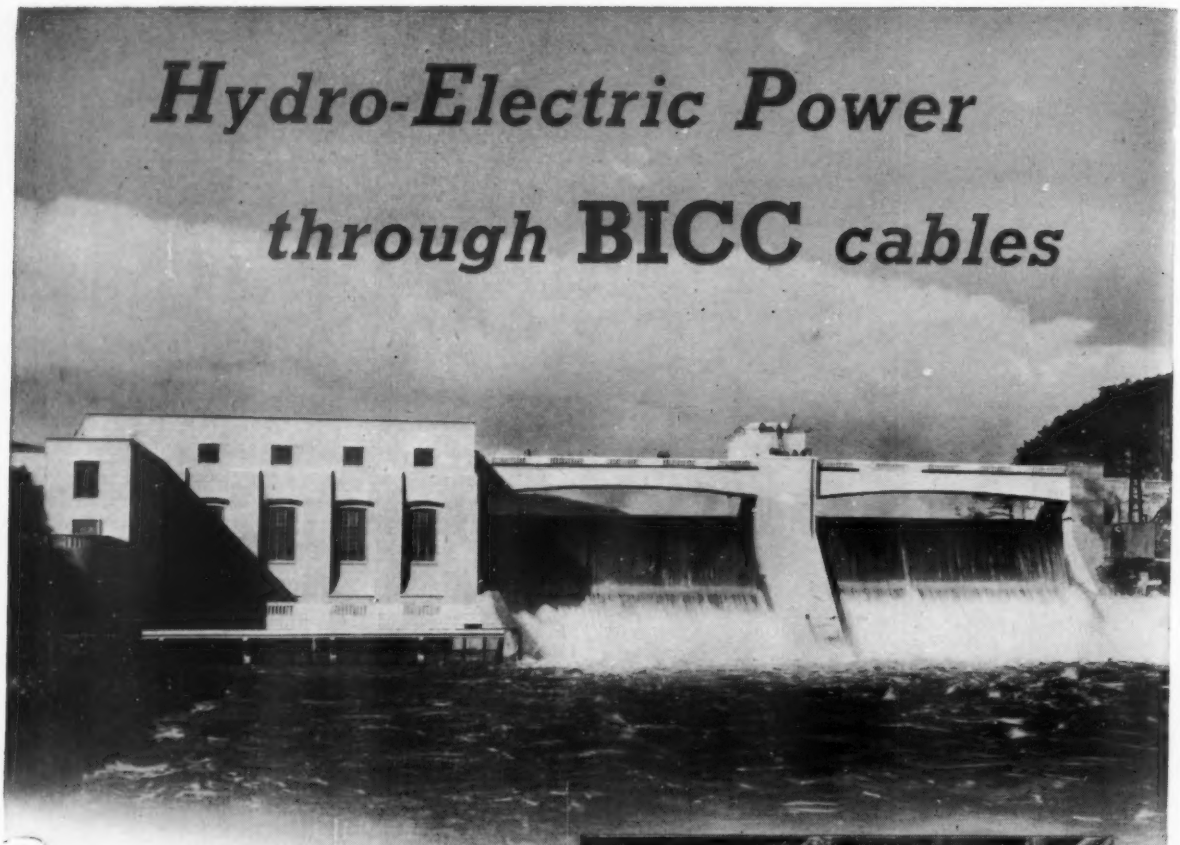
Hydro-Electric Power through **BICC** *cables*

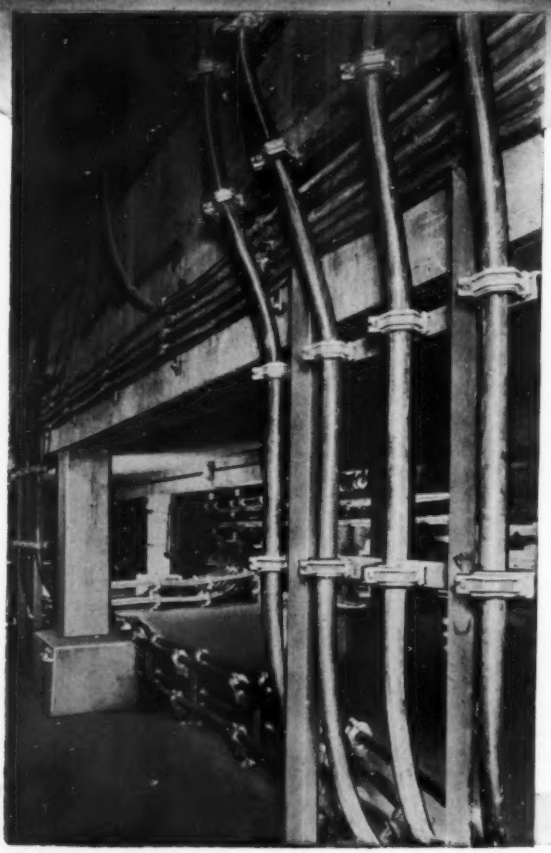


For the two North of Scotland Hydro-Electric Board generating stations at Pitlochry and Clunie, all main power and auxiliary cables were supplied by BICC. This Company also supplied the 3-core 11kV cables and 30-core 7/.029″ auxiliary cables which link the two stations. The installation work was carried out by B.I.C. Construction Company Ltd.—a subsidiary of BICC.

The BICC Organization manufactures, supplies and installs all types of cables for hydro-electric work all over the World.

Above: *General view of Pitlochry Generating Station.*
Right: *Run of 11kV cables from switchgear to transformers at Clunie Generating Station.*

Consultants: Merz & McLellan.



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Shortage of Men

ONE special theme has been noticeable, in recent months, in the reports of engineering conferences and in the columns of the technical press in various parts of the world, particularly in America: the ever-increasing demand for electricity has caused the Public Utility Authorities to step up their large-scale plans for reinforcing power supply, and they are finding that among the many shortages which confront the engineering economy of almost every country in these difficult rearmament days, one of the most serious of all is the shortage of skilled personnel.

Specialists design and build power plants. The supply of specialists is not so restricted as that of all-round men who have to take the responsibility of running and maintaining the increasingly complex power plants on which the world now entirely relies.

In Great Britain, the attention of both the North of Scotland Hydro-Electric Board and the British Electricity Authority has had to be focused very sharply on the formulation of schemes of every kind for the training of engineers to run their new power plants. Vast sums of money have been spent on training courses, both for artisans and for technical staffs.

The difficulty which confronts those concerned with the supply side of hydro-electric engineering rather than with construction is that there is little glamour attached to the running and operation of a hydro-electric plant.

The steam-power-station engineer has before him several incentives which are not present in hydro-electric schemes. To start with, from the purely professional engineering point of view, he has the continual challenge of endeavouring to increase the efficiency of the station. Any man with science in his blood must feel secretly ashamed of being associated with an enterprise which calmly throws away two-thirds of the raw material which is bought at such a high cost in money and man-hours, and which forms so large a share of the country's irreplacable national assets. He can perhaps devote his thoughts towards an improvement in thermal efficiency of even one-tenth of one per cent. He may endeavour to transfer to a power plant in which newer and more up-to-date equipment is being installed; his power station may well be extended so that his responsibility and his opportunities are increased.

The man working in the hydro-electric plant, however, has few of these incentives. There is little he can do to increase efficiency once the plant has been put into operation. There are no signs of entirely new principles in hydro-electric utilisation practice comparable, for example, with the cyclone boiler, the original introduction of pulverised fuel, higher steam pressures, and hydrogen cooling, which have characterised major advances in steam-power-station practice during the last two decades. He may very probably have to reside in a remote district, cut off from professional associations and from the amenities for himself and his family which steam-power-station engineers can generally enjoy.

The situation in regard to hydro-electric engineers is complicated by the fact that the man in charge of a large water-power plant needs to have basic skills in civil engineering, in hydraulics, in mechanical engineering and in the art of the electrical engineer as well. The kinds of theoretical and practical training which lead to so wide a knowledge is seldom found in places other than the few special training colleges —such as that established at Pitlochry by the North of Scotland Hydro-Electric Board—which have been established specifically for this purpose. The learned Institutions, who set the standard for corporate membership of the professional bodies to which engineers belong, have discussed many aspects of training of engineers in recent years. It is feared, however, that in their rigorous demands for ever higher standards the trend of the majority of the discussions has led towards the creation of a climate of engineering training which specialisation is fostered and nourished.

It is not to be suggested that artificial glamour should be added to the work so vital to the whole community of operating and maintaining the world's hydro-electric plants. It may well be, however, that other means of attraction can be found. The provision

of living accommodation on a high scale, the opportunity for occasional travel to other hydro-electric plants to exchange views and opinions with engineers engaged on similar tasks, the establishment of competitive yardsticks for efficiency in regard to such matters as rapidity of maintenance overhauls, lack of outages due to failure and the like, might well inject into this essential branch of the engineering profession a new appeal. Unless some such action is taken the desperate note we detect in the enquiries constantly being made by Supply Authorities in many countries for men to fill the posts created by the constant procession of new hydro-electric plants may take on an even sharper pitch.

Snowy Mountains Scheme

THE second annual report of the Snowy Mountains Hydro-Electric Authority was presented to the Federal Parliament during March by the Minister for National Development, Senator W. H. Spooner. The salaried staff of the Authority increased from 296 at July 1, 1950, to 718 by June 30, 1951, and comprised 385 professional and technical officers and 333 administrative officers. At the end of the financial year wages employees totalled 1,650—an increase of 561 during the year. The foregoing figures are exclusive of staff and employees of the Government and semi-Government bodies that are carrying out work on behalf of the Authority and of staff and employees of contractors.

Faced with an acute shortage of engineers in Australia and wishing its programme to proceed as rapidly as possible, the Authority decided to embark upon an overseas recruitment programme. By June 30, 1951, over 100 professional staff (mainly engineers) had been recruited overseas and 60 additional professional men from abroad were engaged in Australia. By June 30, 1951, nearly 400 German tradesmen engaged by the Authority had arrived in Australia and were at work in various parts of the Snowy Mountains area.

Progress at Owen Falls

THE annual report for 1951 of the Uganda Electricity Board reveals satisfactory progress on the Owen Falls scheme.

The rock-crushing and screening plant for producing the aggregate from amphibolite rock excavated on site was commissioned in April and the automatic weigh-batching plant in May. The cofferdam for the power house to protect sets 1-4 was completed and dewatered in March, and the remainder of the cofferdam, for sets 5-10, was commenced in October and has now been completed. As a result of experiments carried out on site it was found possible to use the local murram for constructing this cofferdam and consequently it was possible to release for other uses the steel sheet piling which was intended for this work and to effect an appreciable saving of time and construction.

Excavation for the portion of the main dam within the cofferdam, which was dewatered towards the end of 1950, commenced in January and concreting of the main dam was started on September 5. Concreting of the power-house foundations commenced in May, and good progress was maintained so as to enable the target date for the first stage of the accelerated programme to be met. The erection of structural steelwork for the power house commenced on December 1. The total concrete placed to the end of 1951 amounted to 7,200 cu. yards, of which 4,000 cu. yards were in the main dam.

By the end of 1951 preparations had been completed for precasting the concrete structures for the outdoor switching station.

Over the year a number of site investigations were carried out to determine the extent and nature of cut-off walls required at the ends of the main dam. As a result of these investigations it was decided that the river banks could be treated as natural earth dams and that extensive cut-offs would not be required, thereby affecting a considerable saving in cost and time.

Net expenditure on the scheme up to the end of 1951 is given as £2,329,000, and the estimated capital expenditure up to the end of 1956 is £9,988,500. This includes the whole of the civil engineering work for ten 15,000 kW sets and the installation of six of them.

Quebec Power Company

THE annual report of the Quebec Power Company states that although the company sold more power and revenues for 1951 were greater than ever before, its net earnings decreased to $1.17 per share from the previous year's $1.31 because of the higher rate of Federal Income Tax. Sales of electricity rose 12·4 per cent. during 1951 to an all-time record of 515,349,985 kWh, of which 204,631,447 kWh were produced in the company's own hydro-electric plants. Most of the increased demand was centred in Quebec City and district, but at the same time the consumption on the South Shore rose so steeply that two new high-voltage lines had to be built earlier than planned. Three new substations were built and four others extended. Capital expenditures totalled $1,585,619.

Revenue from power sales was $6,935,890, an increase of 9·6 per cent. over 1950. Revenue from gas sales within Quebec City was $576,523, a decrease of 2·6 per cent. reflecting the trend toward replacement of gas by electricity for cooking. The company's gross revenues were $7,696,447, an increase of 8 per cent., while operating expenses were $5,033,051, an increase of 8·7 per cent. Depreciation increased to $840,000 from $775,000, and the provision for Income and Profits Taxes rose 38·6 per cent. to $673,572 from $485,879. The net income available for dividends declined 10·7 per cent., and dividends of $1 a share, as in the past, were paid for the year.

Shawinigan Annual Report

THE 1951 report of the Shawinigan Water and Power Company shows that power sales during 1951 achieved a record at $34,651,194, an increase of 18·4 per cent. over 1950. Capital expenditure amounted to $12,917,000, including completion of the Trenche development on the upper St. Maurice river, the transmission and terminal installation necessitated by that development, the extension of urban and rural distribution systems, the increase in the voltage of the lines from Isle Maligne to Quebec, and the establishment of a new headquarters building at Victoriaville for the divisions south of St. Lawrence and east of Montreal. During the year 53 new industrial plants and 10,193 other new customers were connected, and by

the end of the year 186,217 customers in 590 municipalities were receiving service.

New French Project

DETAILS of a project for the construction of a dam and hydro-electric station at Serre Poncon, on the Basse Durance, in the region of Marseilles, have now been made known. It is estimated that a new reservoir will hold about 1,200 million cu. m. of water and that its electricity production capacity would be in the region of 1,000 million kWh per year. It is announced that all the details of the barrage design have been completed and that irrigation of agricultural land will benefit when the structure is completed, as well as the general benefit from the production of electricity. The engineers have also stated that the size of the reservoir should also alleviate some of the damage caused by flooding of rivers in the area.

It is believed that work on the new barrage will start shortly and that the construction and installation will be completed by 1958. The work will include the construction of an 80 km canal which will take an inflow from several rivers.

Pi River Scheme

ONLY about one per cent. of the very large water-power potential which exists in China has yet been harnessed, and in view of the inclusion of the greater part of the country behind the iron curtain, we are not likely to hear much about the various large-scale plans which have been promulgated from time to time. Thus the news that construction work has actually started on the Pi river scheme, in Anhwei province, some 100 miles to the west of Nanking, is of special interest. Full details are not available, but the dam is to be 70 m. high, and in view of the regular flooding which takes place in the Pi river valley, a dam of such a size is likely to exercise a considerable influence on the control of irrigation and flooding. As well, it will provide a reservoir of a size which augurs that a large amount of power will ultimately be made available to the local timber industries.

Progress in Pakistan

IN spite of the many reports from Western Pakistan, during the last few years, that large-scale hydro-electric projects have been inaugurated or planned, so far only the original station at Malakand is actually in commercial operation, although work on other projects is steadily advancing. Finance has been one of the major difficulties, and the recent visit to the North-West Frontier Province by Mr. Eugene Black, the President of the International Bank of Reconstruction and Development, may result in additional financial facilities.

The Malakand scheme, established in 1937, has been extended from its original capacity of 9,600 kW in three units by the addition of two 5,000 kW units in 1951.

Among other major schemes is one at Dargai, where 20,000 kW of plant is being installed in the form of four 5,000 kW units of American manufacture, operating under a head of 250 ft. It is hoped that this will be in operation early in 1953.

The Warsack scheme was first mooted in 1949, but there was much opposition from Afghan interests, since the station is planned for installation on the Kabul river which finds its source in Afghanistan. The very large amount of 180,000 kW of plant is planned for this station, which is modelled on Swedish practice. Only the earliest stages of construction have yet been reached, and the ultimate completion of the project on the lines first planned is not entirely certain.

The Pakistan Prime Minister, inaugurating a new steam station last month, said that since a shortage of electric power was likely to exist in the country for a considerable time to come, it was necessary for the Government to exercise a strict control of the utilisation of electricity.

Italian Plant for Greece

THE Greek Government, since the war, have devoted a very high percentage of their available capital investment resources to augment the country's electric power supply. Although Ebasco Services of America have a five-year contract with the Greek Government to manage the design and construction of a number of power plants in Greece, one of the most important hydro-electric schemes is being constructed by Italian engineers on the Louros river, in the Epirus province on the western seaboard near Yannina. With an initial capacity of 5,000 kW, the station will involve a dam across the Louros river 45 ft. high and 330 ft. long. This is the smallest of a number of hydro-electric schemes, including a 50,000 kW plant on the Ladhon river and a 40,000 kW plant at Agra, on the Vodas river, to serve Macedonia and Thrace.

Power Shortages in New Zealand

FROM New Zealand we hear once again of power shortages in the North Island. The world trend towards a steadily increasing rate of rise of demand is even more pronounced in New Zealand than in many other countries. Whereas in Great Britain, for example, the increased demand in 1951-52 over 1950-51 was 13 per cent, in New Zealand it was no less than 15 per cent. The water stored in the hydro-electric reservoirs is at a low level compared with this time last year. A great deal of work is in progress but strikes, shortages of material and delayed deliveries of plant from overseas have caused great concern to the New Zealand power authorities in recent years, and many of these projects are well behind the estimated completion date.

Japanese Survey

THE Frontier Provincial Government of Pakistan has given its approval to a plan for the harnessing of the waters of the Kunhar river for hydro-electric power. The plan had previously been discussed by engineers of the Provincial Electricity and Public Works Department with the Japanese Industrial Mission which visited the Frontier Province last year. This plan involves damming the Kunhar coming from the Khaghan valley at a suitable place and diverting it on to the Pakhli plain in the Hazara district. Estimates indicate that 60,000 kW of low-cost power can be developed. It is contemplated that Japanese engineers will be employed to carry out preliminary investigation of the site and to prepare the detailed estimates and designs of the project.

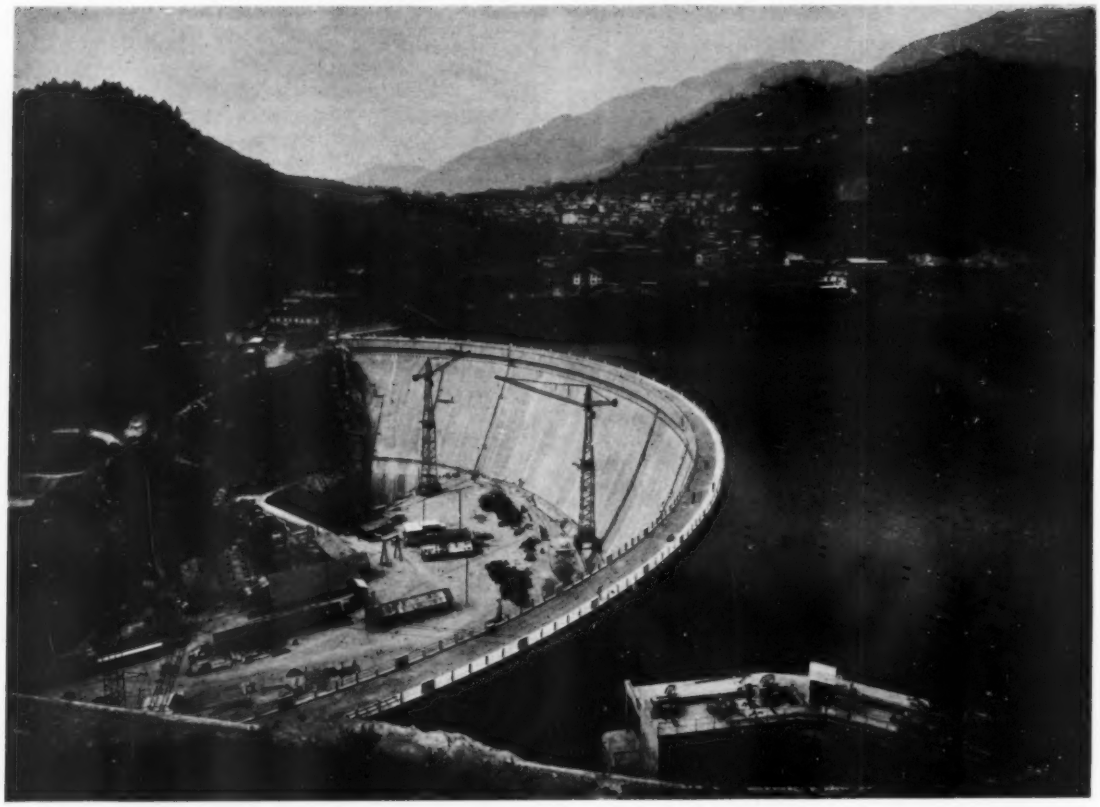


Fig. 1. General view of the Pieve di Cadore dam

Recent Dams in the Eastern Alps

A commentary on a paper recently presented to The Institution of Civil Engineers by Dott. Ing. Carlo Semenza on "The Most Recent Dams by the 'Societa Adriatica di Elettricita (S.A.D.E.)' in the Eastern Alps"

A MOST interesting paper was presented on March 18 to The Institution of Civil Engineers by Dott.Ing. Carlo Semenza, describing the design of the major dams for which he has been responsible in his capacity as Chief of the Construction Department of S.A.D.E. during the past 25 years. All of the dams described are of arched or dome-shaped form, but each presented an individual design problem. Four dams were discussed in detail in the paper: Lumiei, Pieve di Cadore, Val Gallina and Valle di Cadore, and brief notes were given on the projected dams on the rivers Vajont and Maè.

The arched form is favoured by the topographical conditions, for the dam sites are usually in deep narrow gorges, and as these gorges in many cases extend a considerable distance upstream it has been necessary to carry the dams higher than normal in order to impound an adequate quantity of water. Geologically the district is excellent, the prevailing structure being limestone, mainly dolomite. Any defects are obvious on inspection, and water permeability in the direction of the rivers is very low.

The Lumiei Dam

The dam at Maina di Sauris on the river Lumiei, completed in November 1947, was fully described in an article which Dr. Semenza contributed to this journal in 1950*, and Figs. 2 and 3 are taken from that article. It is 134 m. high from the lowest foundation

*"An Underground Station." By Dott.Ing. Carlo Semenza. WATER POWER, July-August 1950, page 144.

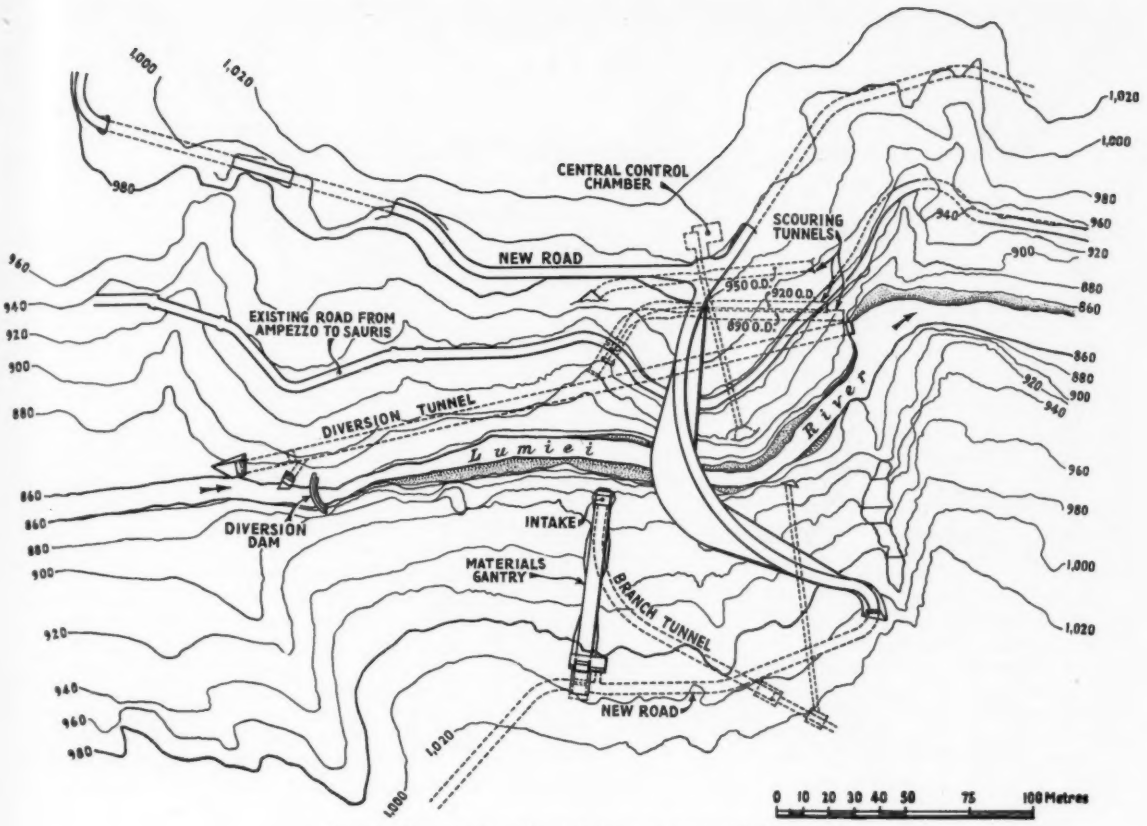


Fig. 2. Plan of the Lumiei dam and associated works

to high-water level, and the top chord is 130 m. The crown thickness is 16 m. at the base and 3·15 m. at the top, the increase of thickness at the abutments being from 20 to 30 per cent. The dam is a triangular dome-shaped shell which has been made absolutely symmetrical by an excavation in the right bank. The greater volume due to the increase of space was balanced by the reduction of thickness due to the absence of abnormal twisting stresses, and it was evident from Dr. Semenza's remarks that he attached considerable importance to symmetrical construction.

The thrust from the dome perimeter is transmitted to the rock faces by a reinforced-concrete saddle through a perimeter joint made watertight by several layers of asphaltic sheet and a copper sealing strip. The joints within the dam are at intervals of 15 m. and are mainly vertical and radial except when approaching the perimeter joint, where their direction changes gradually to meet the perimeter joint at right angles. Upstream and downstream faces are lightly reinforced.

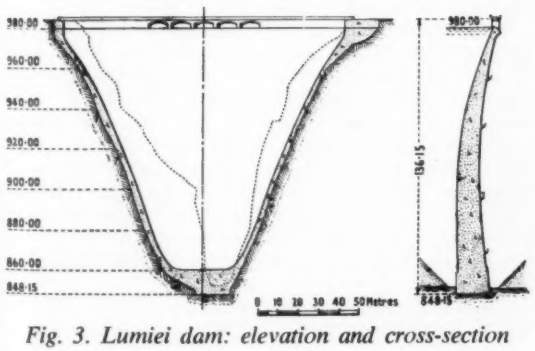


Fig. 3. Lumiei dam: elevation and cross-section

Design computations and model tests were undertaken by Prof Guido Oberti of Milan Polytechnic. The mathematical analysis was based on the Italian regulations of 1931, the dam being divided into independent horizontal arches at intervals of 10 m. starting from the crest, which were considered to be subjected to hydraulic pressure and thermal stress. The theory of the hyperstatic elastic arch fixed into the abutments was applied, allowance being made for shear in the case of arches having a high thickness/length ratio. Arches below + 900·00 m. (see Fig. 3) were calculated by the theory of thick rings.

A ferro-pozzolanic cement of high resistance was chosen for the concrete, the normal 1 : 3 mortar giving a 28 day compressive strength of 709·5 kg. per sq. cm. The composition of the concrete was as given in Table I, and cubes of concrete cut from the dam itself had compressive strengths ranging from 528 to 691 kg. per sq. cm.

Pieve di Cadore Dam

An outline of the Piave-Boite-Vajont scheme has just been given in this journal by Dr. Mainardis

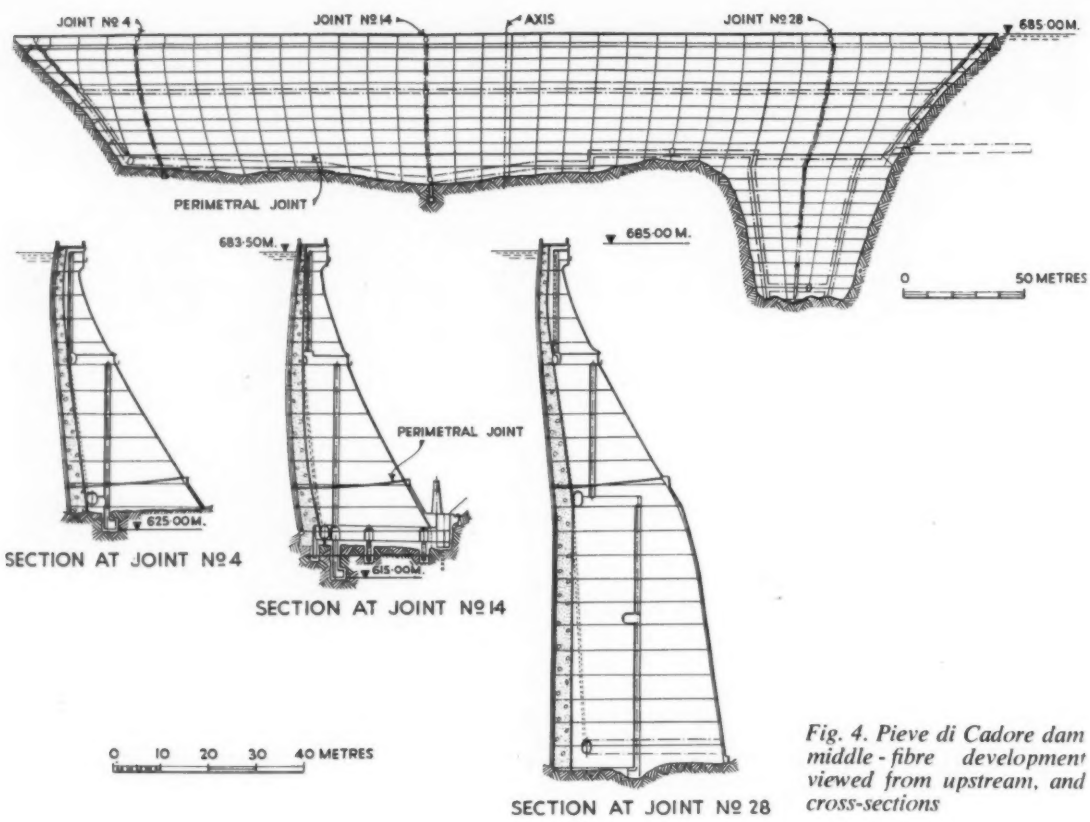


Fig. 4. Pieve di Cadore dam middle-fibre development viewed from upstream, and cross-sections

TABLE I

		Per cent.
Ferro-pozzolanic cement	... ...	10·8
Very fine sand	... ...	1·2
Sand 0-4 mm. (0-5/32 in.)	... ...	22·5
4-10 mm. (5/53-$\frac{1}{2}$ in.)	... ...	7·5
Aggregate 10-40 mm. ($\frac{1}{2}$-1°/$_{16}$ in.)	... ...	28·0
40-80 mm. (1°/$_{16}$-3^{5}/$_{32}$ in.)	... ...	30·0
		100·0

Water/cement ratio: 0·53.

and a view of the Pieve di Cadore dam is reproduced from that article in Fig. 1.† Sections through the dam are given in Fig. 4 reproduced from Dr. Semenza's paper.

The site chosen was not entirely favourable although it was the most suitable one from topographical and geological standpoints. It is cut out in the dolomitic limestone in the form of a trapezium about 300 m. wide and 55 m. high, the floor of the valley forming a rocky plateau. On the right the river Piave flows in a narrow gorge, 55 m. deep, the sides of which diverge downstream and which cuts the plateau in a direction converging towards the axis of the plateau.

The shape and direction of this gorge presented a difficult design problem, and several solutions were considered. The first was to close the gorge with a thin arch and to provide its left abutment on the plateau by means of a big gravity structure; from this point to the left the barrage would have been completed by a solid or hollow gravity dam. Model tests, however, showed that the tension stresses at the base of the structure were high, and to eliminate them it would have been necessary to increase the volume to such an extent that the structure would have been unduly expensive.

Another, and a simple solution would have been a straight gravity dam supported by the plateau and a plug to close the gorge, but owing to the angularity in the direction of the gorge this would have involved considerable excavation of the gorge wall and a large and expensive plug; furthermore, the static conditions at the joint between the plug and the foot of the dam were uncertain.

This pointed to the desirability of crossing the gorge at right-angles, and this in turn led to the idea of an arched gravity dam for the upper structure together with a transverse plug in the gorge. This involved several unknown factors, such as the degree of reliance that could be placed upon the behaviour of a gravity arch of such dimensions, the stress conditions at the transition from arch to plug, and the problem of whether the plug would act as a wedge or a thick arch. An extensive programme of mathematical analyses and model tests was therefore undertaken.

The mathematical analyses were carried out mainly by Prof. Filippo Arredi of Rome University, who

†"Soverzene Generating Station." by Dr.Ing. Mario Mainardis, WATER POWER, March 1952, page 95; April 1952, page 124.

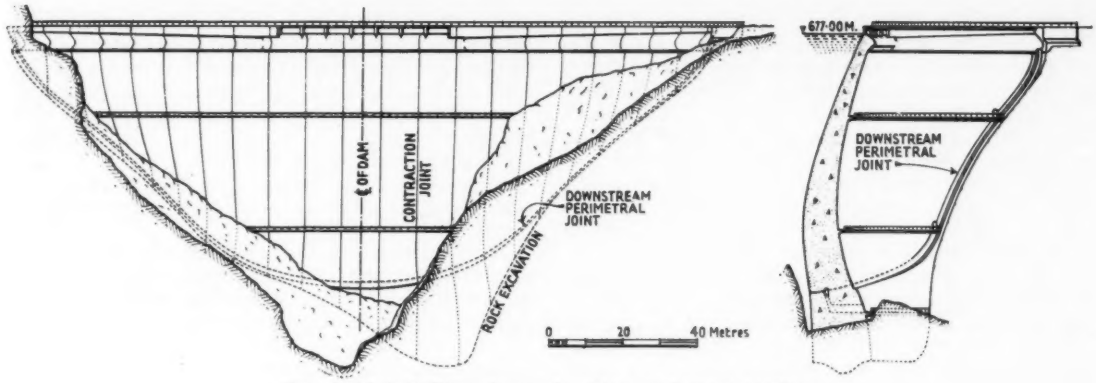


Fig. 5. Val Gallina dam: elevation and cross-section

starting with the studies of Smith, Conté and Tölke, followed mostly original methods. Other studies, based on Tölke's method, were carried out by Prof. Oberti with Prof. Danusso as consultant. Their results were checked by experiments on two-dimensional photo-elastic models, and deflections so obtained embodied in the system of equations covering the imaginary network of arches and cantilevers. In addition, the trial-load method of the American Bureau of Reclamation was carried out by Prof. Tonini.

Finally, a one-fortieth scale model was built in concrete, loaded by a system of hydraulic jacks to represent both deadweight and water pressure, and the resulting movements, which were of the order of 0·01 m., measured. In the light of all these studies a second model was built to a slightly modified shape, and convincing agreement obtained between analytical and model-test results. The percentage of the load absorbed by the arches was much greater than had at first been expected, because the modulus of elasticity of the rock foundation was much inferior to that of the concrete. Further, the structure was found not to conform to the theory of horizontal arches but to behave as a set of arches lying in inclined planes with their crowns high and their abutments low.

The resulting structure has an average height (excluding the plug) of 55 m., a length at the upper arch of 390 m. and a chord of 305 m. The average radius of the arch is 160·9 m., the upper arch being poly-

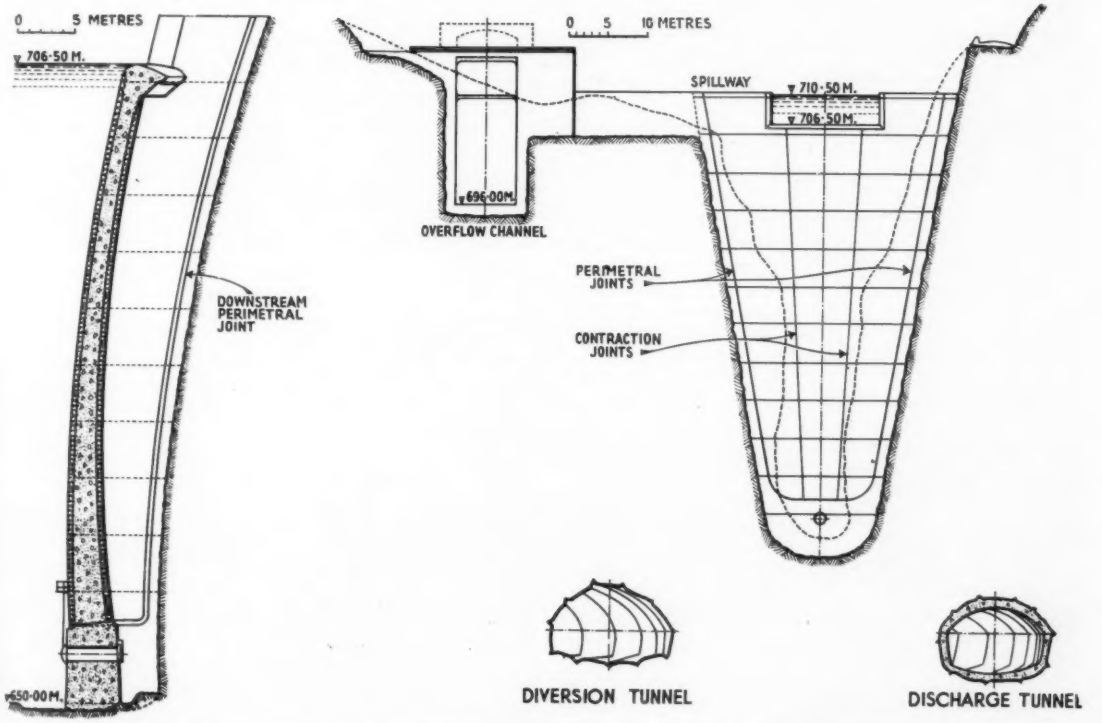


Fig. 6. Valle di Cadore dam: section along middle fibre, and cross-section showing arrangement of facing blocks

centric and the base circular. The thickness at the base is 26 m., which is about 65 per cent. of that of a straight solid gravity dam. Towards the abutments the thickness increases by about 20 per cent. The plug is 53 m. long, and its thickness in the axis of the gorge is 36 m. at the base decreasing to 26 m. where it matches the foot of the dam. A curved perimeter joint is incorporated in both abutments and base. No allowance was made for uplift pressure, and an adequate system of drainage pipes and inspection tunnels was provided.

To minimise temperature effects, resort was made to a low-heat ferro-pozzolanic cement containing 25 per cent. of Roman pozzolana, with a tri-calcium-silicate content of 40-45 per cent., and with an addition of about 1 per cent. of Plastiment. As a result, the maximum temperature rise was no more than 15°C. as against the usual 30-35°C. The concrete mixes used for face and core are given in Table II.

The dam was completed in November, 1949.

TABLE II

	Face-concrete	Core-concrete
	%	%
Cement	9·5	7·6
Sand 0-4 mm.	35·5	26·4
Coarse sand 4-16 mm. ..	23·0	20·0
16-40 mm. ...	16·0	17·0
Aggregate 40-75 mm. ...	16·0	15·0
75·120 mm. ...	—	14·0
	100·0	100·0
Approx. water/cement ratio	0·5	0·55

Val Gallina Dam

The Val Gallina dam, completed at the end of 1951, is of the dome type, and was constructed only after exhaustive investigations, including drilling, tunnelling and grouting tests, since the rock, an Upper Trias limestone, was rather cracked on the surface. The original cross section of the site was far from symmetrical, and symmetry was obtained by blocking the deepest part of the gorge by a plug. Drawings of the dam are reproduced in Fig. 5.

The longitudinal section is shell shaped and the vertical section dome shaped with a pronounced overhang downstream. The height is 85 m. and the chord/height ratios 2·7 : 1 inside the perimeter joints and 2·15 : 1 for the whole construction. Steel reinforcement is provided on both upstream and downstream faces, and the volume of concrete is 98,000 cu. m. Owing to the shell shape a considerable proportion of the load is absorbed by the cantilevers, and important information on this type of construction was obtained from model tests designed and directed by Prof. Oberti.

The cement content of the concrete mix was 250 kg. per cu. m., and was the same ferro-pozzolanic cement as used for the Piave dam during the cold months. Grouting assumed considerable importance, and up to March 31, 1951, a total length of 32,301 m. had been drilled and 25·085 tons of cement injected.

Valle di Cadore Dam

The Valle di Cadore dam was completed in November 1950, and drawings are reproduced in Fig. 6. It is an arch dam, 58 m. high, spanning a narrow gorge, and has two centres, one relating to the upstream face and one to the downstream face. The chord/height ratio is 0·425. Both upstream and downstream faces are protected by precast concrete blocks, the object being to insulate the internal concrete against frost and thaw stresses. It is this internal concrete that is relied upon for design strength. The thickness of the arch immediately above the base, excluding the protection blocks, is 2·77 m.

In conclusion Dr. Semenza referred briefly to the Vajont and the Maè dams, which are in the preparatory stage.

A most interesting discussion ensued, and we only regret that the author's written reply must be awaited to many of the points raised. Dr. Oberti, however, dealt with one or two of the major queries. Great interest was displayed in the nature and purpose of the perimeter joint, and Dr. Oberti explained that its objects were to prevent cracking due to shrinkage and thermal stresses, especially on the upstream side, and to obtain a symmetrical main structure.

On the question of models Dr. Oberti stated that plaster of paris was a difficult material for large structures because it took a long time to dry out and tended to be non-uniform. He had been using a concrete made with volcanic rock, an advantage of which was that the modulus of elasticity could be adjusted to requirements. It was possible to make a model having a modulus of elasticity only one tenth of that of the final structure, with a corresponding advantage in taking measurements.

Dr. Semenza's paper also gave particulars of a comprehensive system of measuring devices incorporated in the actual dams to enable their behaviour in service to be watched. Prof. Tonini reported that good agreement had been found between analytical results, model-test results, and results on the actual dams.

Hydro-Electric Plant for Norway

Norway, in the past widely known for farming, forestry and fishing, is rapidly becoming an industrialised country. This change has been brought about by the increasing development of the country's resources of water power since the war, and it is interesting to record that, although bauxite has to be imported, the availability of cheap electrical power has made it possible to export at competitive prices considerable quantities of aluminium.

It is in connection with a new aluminium plant now under construction at Sunndalsora, that additional hydro-electric plant is to be installed at Aura Kraftonlegg. For this project The General Electric Co. Ltd., Birmingham, England, has been entrusted with the order for a 62·5 MVA, 12·3 kV, 428·6 r.p.m. horizontal-shaft alternator for coupling to an Escher Wyss Pelton wheel. The alternator will be designed and built in the company's works at Witton, Birmingham, and although machines of bigger output have been made, the physical dimensions of this machine will exceed anything previously constructed in the works: in fact, it will be one of the largest horizontal-shaft hydro-electric sets in Europe.

The alternator will weigh over 310 tons, the rotor alone accounting for about 170 tons. Transport difficulties are such that no part must exceed 55 tons in weight and for this reason the machine will be specially designed and constructed so that it can be shipped in sections and erected on site.

Hydro-Electric Projects in North Wales

The British Electricity Authority is putting before the present session of Parliament a Private Bill which deals with extensions of the existing hydro-electric power works at Dolgarrog and Maentwrog and with the construction of a new hydro-electric scheme in the vicinity of Blaenau Ffestiniog

THE present Dolgarrog power station operates on two separate pressure heads, a high head of 1,178 ft. gross from the Cowlyd reservoir in the Carnedd range and a lower head of 855 ft. gross from the small Coedty reservoir above Dolgarrog. The new catchment area to be brought in is on the lower-head section and water collected by leat or open aqueduct in this area will be fed into the Coedty reservoir. The proposals involve the diversion of head waters from the Afon Tafalog or river Ro and abstractions from the Afon Dulyn with other small tributaries. Compensation water will be provided for the Ro and the Afon Dulyn,

Fig. 1. Proposed site of the lower storage reservoir on the Afon Ystradau, Ffestiniog project

Fig. 2. Artist's impression of the lower storage reservoir on the Afon Ystradau

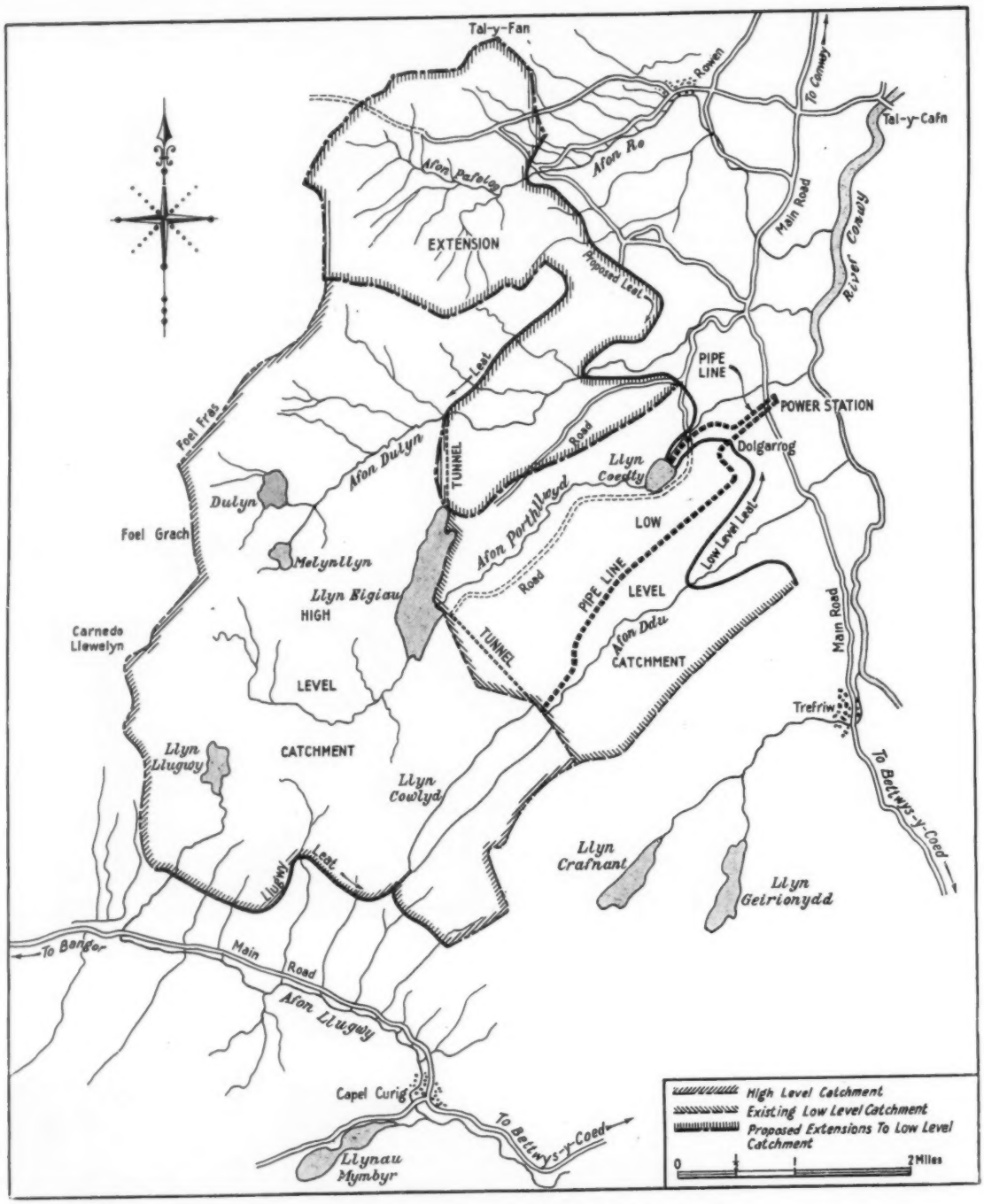


Fig. 3. Map showing the proposed Dolgarrog extension

and piped water supplies will be made available to any farms which are affected along the course of the aqueduct. The existing low-level catchment area will be increased from about 3,400 acres to about 6,800 acres. The scheme is outlined in Fig. 3. Incidentally, Llyn Cowlyd in this figure should have been shown shaded.

In order to make the best use of the extra water run-off from this additional catchment and for better utilisation of the existing high-level storage it is proposed to install two further Pelton-wheel turbo-alternators in extensions to the existing Dolgarrog station, which will increase its normal output capacity from some 18 MW to 28 MW. The existing output of the station will be increased by these means by 13·5 million units per annum above its present average value of some 42 million units.

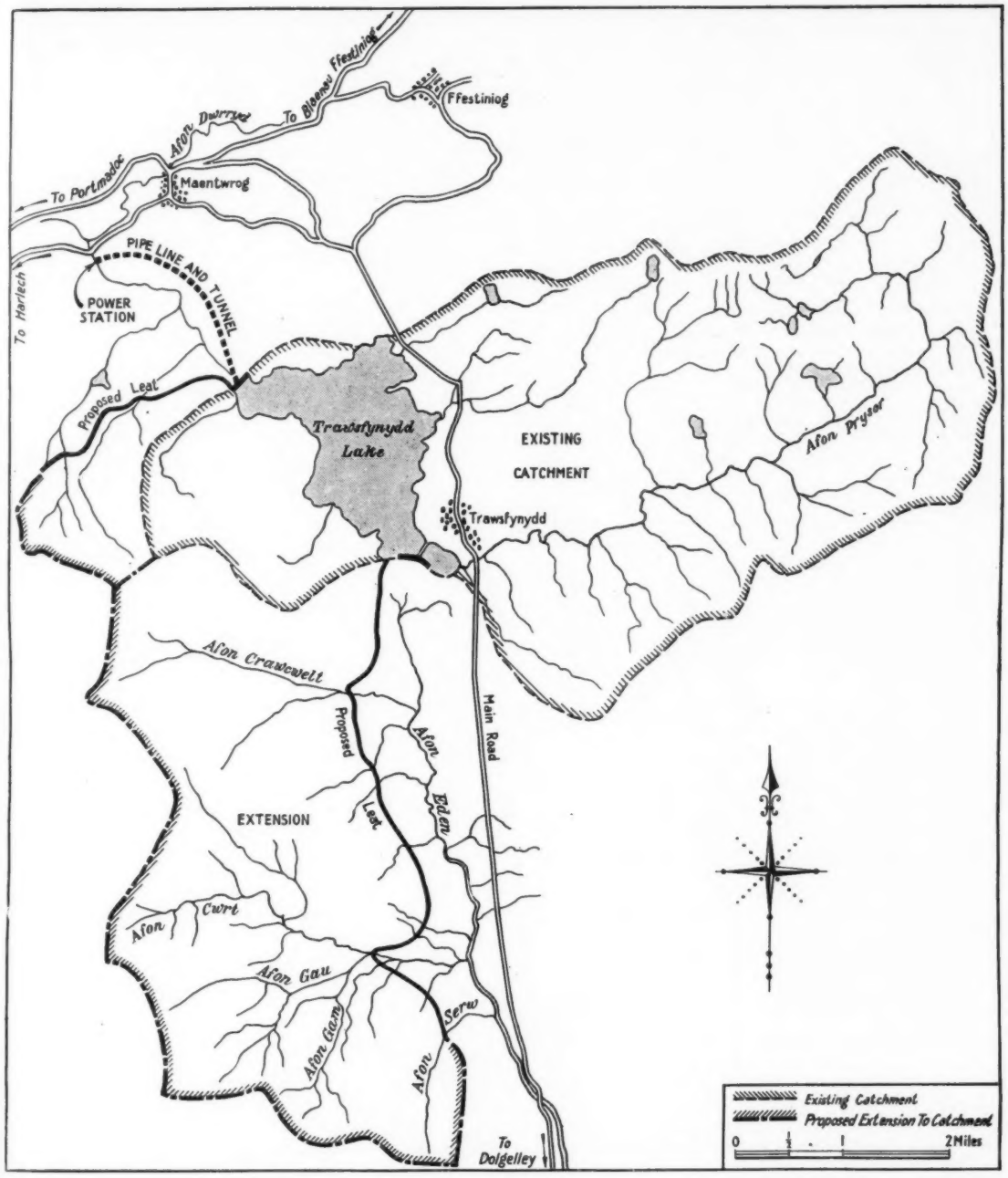


Fig. 4. Map showing the proposed Maentwrog extension

Maentwrog Extension

The existing station at Maentwrog draws on a catchment area of some 22 square miles above and adjacent to the Trawsfynydd reservoir, which forms part of the natural watershed of the river Prysor. The proposed new works would add indirect catchment amounting to approximately 13 square miles and would increase existing generation from 30 million units by 22 million in an average year. The existing generating plant of four 6 MW sets would remain unchanged. The additional catchment would be obtained by the construction of two leats or open aqueducts, the Ardudwy leat, which would divert water from 11½ square miles on a part of the adjacent catchment area of the Afon Eden, and the Llenyrch leat which would add a further 1½ square miles from the Afon-y-Glyn and Prysor catchment west of Trawsfynydd Lake.

The Ardudwy leat will divert water from five streams, viz., the Afon Crawcwellt, the Afon Cwrt, the Afon Gau, the Afon Gain and the Afon Serw, all

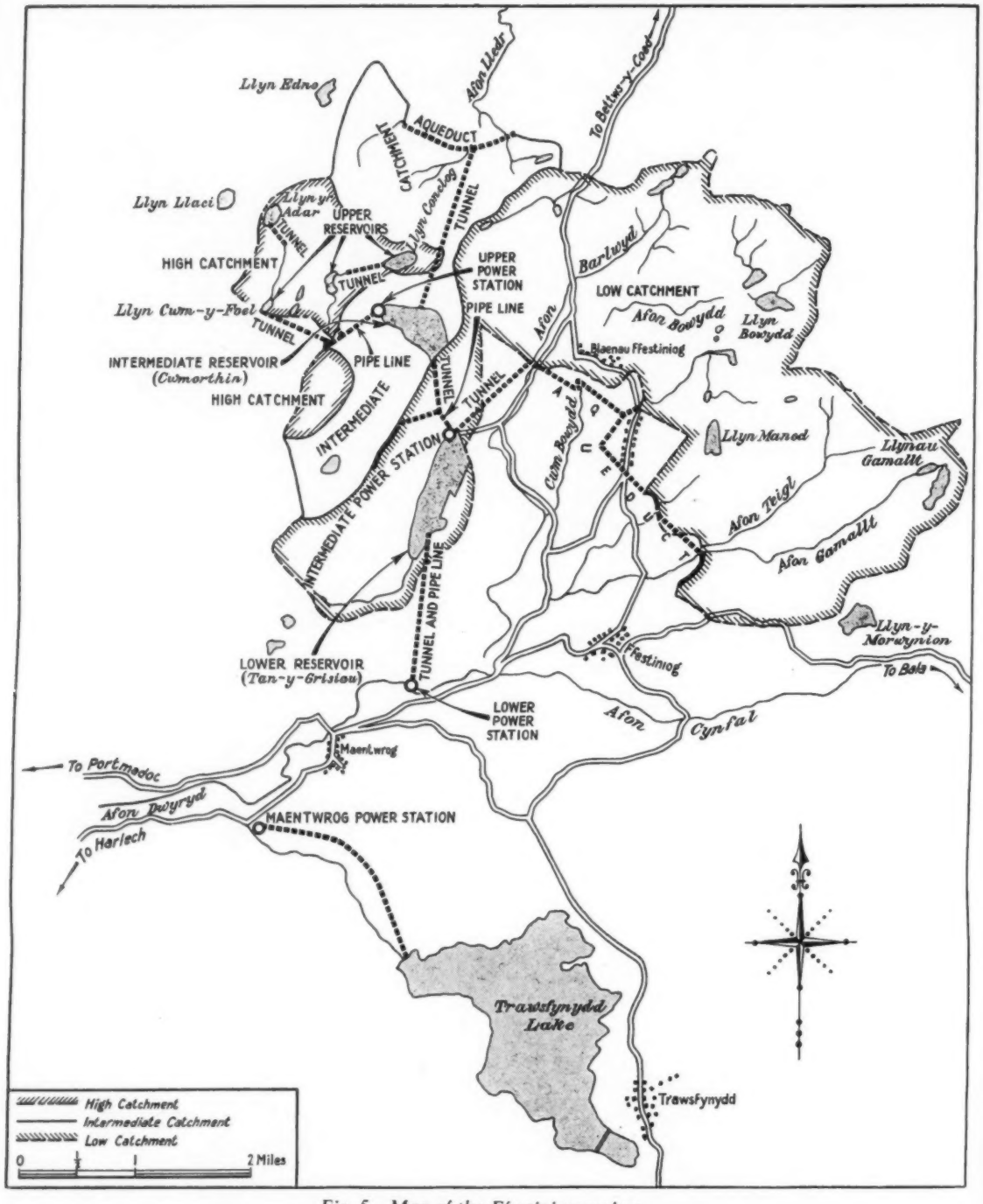


Fig. 5. Map of the Ffestiniog project

tributaries of the Afon Eden, which rises immediately south of the Trawsfyndd reservoir. The total length of this leat will be 6½ miles (see Fig. 4).

The Llenyrch leat will divert water from the Ceunant Gewr, a tributary of the Prysor, and also the head waters of the Afon-y-Glyn, a tributary of the Afon Dwyryd. This leat will be about 1¼ miles in length.

Ffestiniog Project

The arrangement proposed is a three-stage development with reservoirs Llynnoedd Conglog, Corsiog Adar and Cwm-y-Foel, the last-named at an operating level of 1,460 ft. O.D. for the upper stage, Llyn Cwmorthin at 1,123 ft. O.D. for the intermediate stage and a reservoir on a site at Tan-y-Grisiau at a level of 645 ft.

O.D. for the lower stage. The lowest generating station will discharge at a level of below 20 ft. O.D. and the gross head utilised will be about 1,400 ft. through the three stages. The scheme is shown in Fig. 5.

The catchment area is in the northern part of the County of Merionethshire and consists of mountainous country surrounding the slate-mining town of Blaenau Ffestiniog, which is some five miles from the existing Maentwrog hydro-electric station. The land, being high lying, is used chiefly for grazing, but includes numerous slate mines, now mostly disused, and also the town of Blaenau Ffestiniog and the adjoining village of Tan-y-Grisiau. This area is almost entirely excluded from the North Wales National Park, mainly on account of the despoliation of amenity values through former slate mining. The natural catchment drains into the Afon Dwyryd in the Vale of Ffestiniog. It will be increased by the diversion, by leats and tunnels, of water from adjacent watersheds situated to the North and West of Blaenau Ffestiniog, including a small area in Caernarvonshire.

Storage will be provided for the upper stage by the enlargement of the two natural lakes, Llyn Conglog and Llyn Corsiog, and in the existing reservoir at Llyn Cwm-y-Foel. A new dam will be built at Llyn Conglog about 27 ft. high and another at Llyn Corsiog about 22 ft. high. The water from these two storages will be controlled by hand valves and conveyed to Llyn Cwm-y-Foel reservoir along an improved watercourse to a shaft leading to a pressure tunnel. These works will provide a storage of 25 million cu. ft. at a level of 1,460 ft. O.D. This is equivalent to 0·15 million kWh in the upper stage and 0·70 million kWh through all three stages of the development.

Llyn Cwm-y-Foel will be directly connected to the upper generating station by means of a pressure tunnel of about 6 ft. in diameter terminating in a 4ft. diameter pressure pipe on a total length of a mile. Connections to the pressure tunnel by shaft will be made to receive water from Llyn Conglog and Llyn Corsiog as stated. When the station is not operating, the flow in the pressure tunnel will be reversed and the water from this source will increase the storage in Llyn Cwm-y-Foel. The generating station, which will be situated at the upper end of the intermediate reservoir (Llyn Cwmorthin), will operate within a mean head of 320 ft., and the plant capacity proposed is 2·5 MW. The output expected in an average year is 2½ million kWh.

The direct catchment for the intermediate stage will be supplied from the upper-stage catchment and from the southern slopes of Moel Druman and the northern slope of Moel-yr Hydd, which drain into Llyn Cwmorthin. The total area will be about 0·95 square miles, with an average rainfall varying between 120 and 140 in. per annum. Indirect catchment will be diverted to provide a total gathering ground for this stage of about 3·25 square miles, excluding the upper stage. The indirect catchments will be obtained from the northern side of Moel Druman by an open aqueduct about a mile long, taking water from head streams of the Afon Lledr and a tunnel about 6 ft. diameter and 1½ miles in length, through Moel Druman to Llyn Cwmorthin, and also from the head waters of the Afon Stwlan. The intermediate reservoir will be formed in Llyn Cwmorthin by raising the level from 1,049 ft. O.D. 1,123 ft. O.D. by a dam about 80 ft. high and 1,170 ft. long at the lower end of the lake. The storage provided in this reservoir will amount to 265 million cu. ft., equivalent to 5·60 million kWh when developed through the two lower stages of the development. The water will be conveyed from Llyn Cwmorthin by a tunnel about 6 ft. diameter, the lower end of which will be joined to the generating station by a steel pipeline on the hillside about 5 ft. diameter and 1,500 ft. long. The generating station for the intermediate stage will be at the southern extremity of the village of Tan-y-Grisiau and will operate under a mean head of 455 ft. The capacity proposed is 12 MW. The average annual output will be 10·5 million kWh.

The lower reservoir will be formed in the natural basin on the Afon Ystradau near Tan-y-Grisiau. The general level of the basin is about 590 ft. O.D. and the dam, about 65 ft. high, will provide a reservoir with a top water level of 645 ft. O.D. and a storage of 222 million cu. ft. Allowing for the reservation of compensation water, there will be 208 million cu. ft. available for power purposes.

The water will be conveyed from this reservoir to the power station by pressure tunnel, about 8 ft. diameter, on a total length of about 1¼ miles. The station will be on the right bank of the river Dwyryd in the Vale of Ffestiniog, about a mile upstream of the village of Maentwrog. The mean operating head of the station will be 600 ft. and the output in an average year will be 36 million kWh. The plant capacity proposed is 21 MW. The total power capacity of the scheme will be 35·5 MW and the total output in an average year will be 49 million kWh. Figs. 1 and 2 show existing conditions on the Afon Ystradau near Tan-y-Grisiau and the conditions as they will be when the proposed lower dam is completed.

Control Battle for Japanese Hydro

A brisk battle over government control versus private enterprise has developed in Japan over proposals for the development of water power.

The Japanese government's Electric Power Development Bill, recently introduced in the National Diet, provides for the development of hydro-electric power by a special semi-government corporation capitalised at £100,000,000. The Public Utilities Commission—the government agency controlling electricity production in Japan—is opposed to the measure and advocates the formation of a private development company with the nine existing regional power companies as the nucleus. To which the Economic Stabilisation Board and the ruling Liberal Party retort that the nine companies have not the capacity to raise the huge sums necessary for power development, and further, that as government money must be used in large amounts, the government must exercise control.

Public Utilities Commission statistics state that the development plan will create 5,600,000 kW of hydro-electric power and 1,520,000 kW of steam-generated power—a total of 7,440,000 kW (including additional power from the improvement of existing installations) by 1956.

Advocates of private enterprise assert that it would prove more efficient than bureaucracy, that foreign investors would prefer to place their money with private operators, that a powerful single corporation would be tantamount to the revival of the wartime monopolistic "Japan Power Generation and Transmission Company," and that the progressive development of the existing nine regional power companies would be crushed.

Fig. 1. Blasting the downstream rock plug of the diversion tunnel

Manicouagan River Development

Preliminary particulars are given of this scheme which is being undertaken by the Manicouagan Power Company—a subsidiary of the Quebec North Shore Paper Company.

THE Manicouagan is the largest river entering the Gulf of St. Lawrence east of the Saguenay and traverses the area from which the Quebec North Shore Paper Company derives its pulpwood. To the north this area forms part of a vast tundra region, a circumstance that makes the river subject to flash floods of such severity as to require engineering precautions of the first magnitude. In devising the working operations, therefore, it was considered necessary to anticipate a possible flood of no less than 360,000 cusecs.

At the site chosen for the dam, Fig. 3, the course of the river is deviated by a rocky projection and flows in two streams to form an island, subsequently passing

through a narrow parallel-sided gorge containing two series of falls which are instrumental in creating a substantial part of the available head. In erecting the dam, the construction of a normal cofferdam was ruled out because of the devastating flash floods and the fact that the river bed was exceptionally uneven. After considering various alternatives, it was finally decided to construct a tunnel to carry the entire flow of the river by a direct path to the downstream side of the falls. In this way the original loop formed by the river was short circuited and dewatered, so leaving the bed dry for the erection of the dam foundations. This direct channel is 1,600 ft. long and has an equivalent diameter of 35 ft.

As is now customary in operations of this kind a hydraulic scale model of the river and station site was constructed to a scale of 1 ft. to 200 ft. horizontally and 1 ft. to 50 ft. vertically, the finished model occupying a floor space measuring 40 ft. by 30 ft. Accurate contours were moulded in sand to the appropriate scales and consolidated with cement, the test flows up to the equivalent of 360,000 cusecs were studied for 12 months before the final engineering design was determined. To provide protection against damage caused by waves, the top of the main dam wall, apart from the spillway sections, will be built up to an elevation of 5 ft. above the maximum water level. At the spillways the discharge level will be 1 ft. above normal operating level, this margin having been decided as being adequate to protect the power house and roadways after studying flood conditions simulated in the model.

The turbines will normally operate under a head of 125 ft., and initially the plant will

Fig. 2. Downstream tunnel mouth and upstream plug being blasted

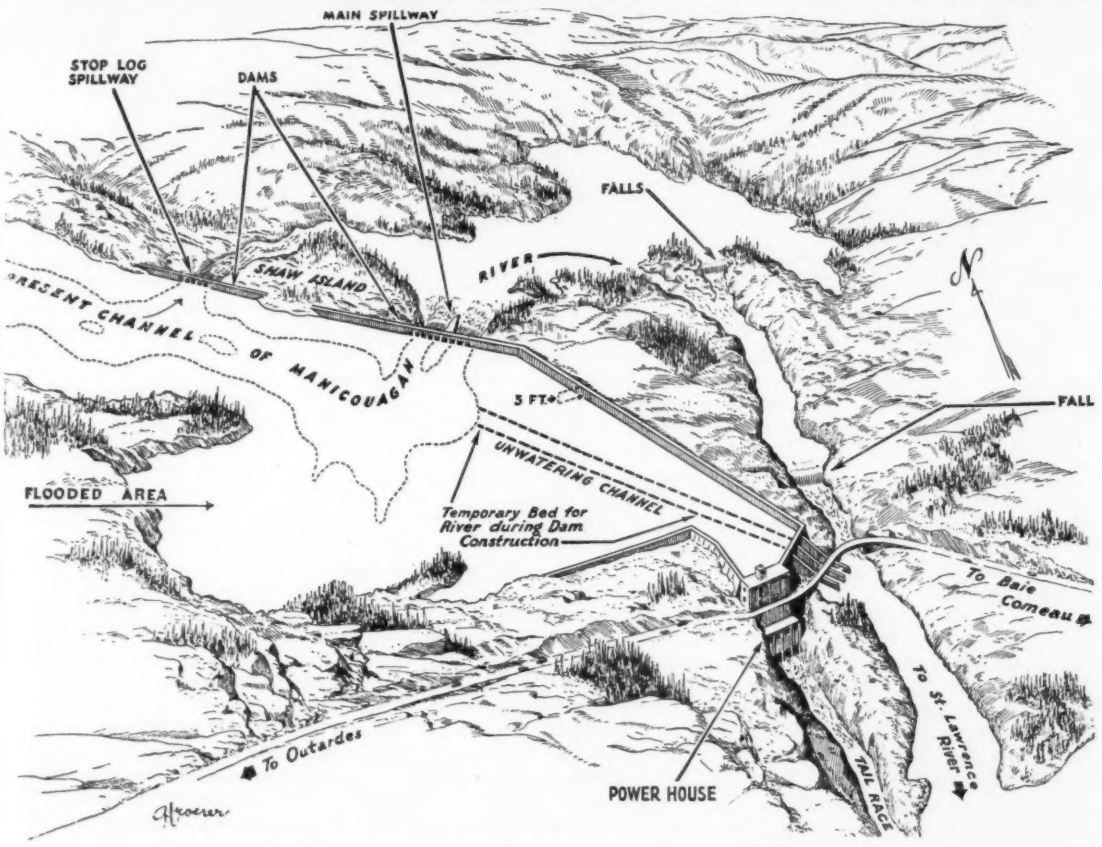


Fig. 3. Perspective sketch of the Manicouagan development

Fig. 4. The river flowing into the diversion tunnel, leaving the original bed virtually dry

consist of a single generator set of 45,000 h.p. capacity. A second and similar set will be added later and ultimately six sets will be accommodated. The resulting energy will be transmitted to the Baie Comeau mill of the paper company and will suffice not only to ensure all anticipated expansions there but will also provide the electrical needs of the communities that are growing up on the North Shore as a result of various pioneering developments.

The dam will have a total length of 4,630 ft. and will have a maximum height of 96 ft. and will create a lake about 11 miles in length. Together with the power station and other ancillary works the dam will require some 135,000 cu. yards of cement. As will be seen from Fig. 3 the power station is to be incorporated in the dam structure and will be connected to the river again by a tailrace about 1,200 ft. long.

The excavation of the diversion tunnel has now been completed, the rock plugs at the ends being blasted in December 1951. These plugs were each about 150 ft. in length, leaving a barrier containing 7,000 cu. yards of granite at the upstream end and 2,000 cu. yards at the other. For the smaller plug four tons of dynamite were used, the resulting explosion being pictured in Fig. 1. A view of the tunnel mouth is given in the foreground of Fig. 2 which also shows the blast that disintegrated the plug at the upstream end. To accommodate the dynamite used in this operation, 5 ft. diameter pilot tunnels were driven 45 ft. below the surface and lateral holes drilled to afford a good distribution of the explosive face. These lateral holes were designed to shatter the rock before the main blast was initiated in the explosive-filled tunnel itself. The results were eminently satisfactory and Fig. 4 shows how satisfactorily the flow is being accommodated, leaving the old river bed virtually dry.

In addition to regularising the flow for power purposes the dam will provide a safe holding ground for the pulpwood floated down from the paper company's timber limits on both sides of the river. For many years it was believed that it would be too expensive to harness this tricky river for the handling of pulpwood, and attention has been given to smaller and more tractable streams.

The scheme is being carried out under the general direction of Arthur A. Schmon, President of the Manicouagan Power Company, with M. H. Jones in charge of the engineering and constructional work; H. G. Acres and Company are acting as the consultants.

Plaque to Sir Edward MacColl. Lord Cooper, Lord Justice General, recently unveiled a plaque to the memory of the late Sir Edward MacColl at Pitlochry Power Station. Sir Edward MacColl was the Deputy Chairman and Chief Executive Officer of the North of Scotland Hydro-Electric Board from its inception in 1943 until his death in June, 1951, on the eve of the official opening by Lady MacColl of the Board's Tummel-Garry Scheme. Lord Cooper was the Chairman of the Committee appointed in 1941 by Mr. Thomas Johnston, who was then Secretary of State for Scotland, to investigate the harnessing of Highland water power. This Committee's recommendations led to the establishment of the Hydro-Electric Board.

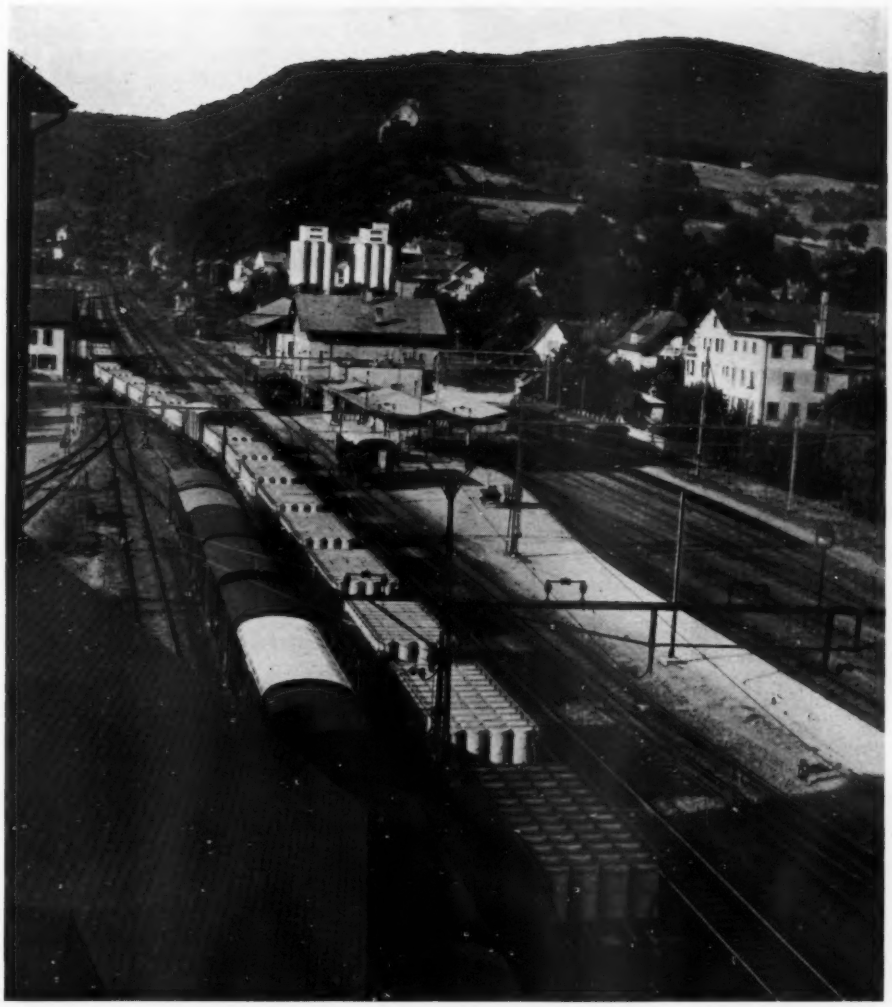


Fig. 1. Wildegg cement plant showing loaded train in the railway station

Cement Transport

On the Continent there has been a considerable development in the transport of cement in bulk, particularly for hydro-electric projects, by means of steel containers for which labour-saving handling equipment has been devised.

DURING a recent trip to Italy and Switzerland which involved a great deal of travelling, the writer was surprised to see the frequency with which both road lorries and railway trucks were loaded with cylindrical steel containers the like of which he had never seen before. On enquiry it was ascertained that the containers were used to transport cement, this method being claimed to have substantial advantages compared with other forms of transport for this commodity. In mountainous regions, where the majority of hydro-electric schemes are situated, it is frequently necessary to transfer cement from, say, broad-gauge to narrow-gauge railway and from narrow gauge to road lorry and possibly from the road lorry to an aerial cableway.

Each transfer involves a handling charge and if the handling is done by manual labour the total charges may add considerably to the final cost of the cement on site. As the containers offer every scope for simplifying and systematising the whole sequence of transport operations, there is not only a saving in cost but also in time; moreover, as the

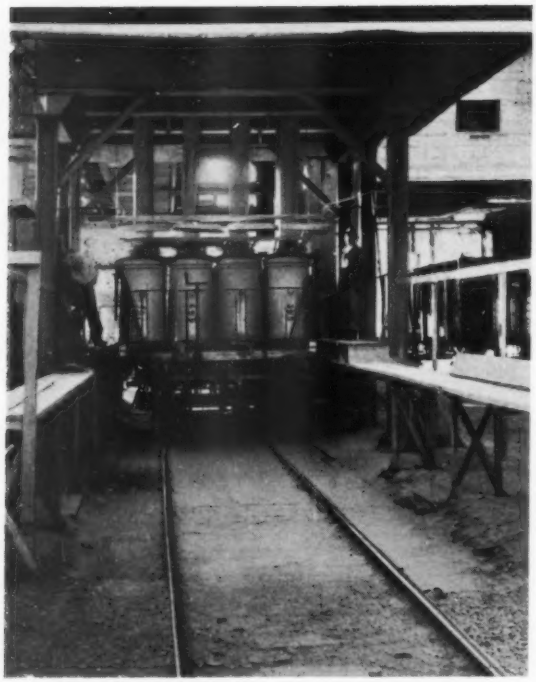


Fig. 2. Loading containers at the cement works

containers can be used indefinitely there is a saving in materials.

Under the "TM" system* as it is called it is possible to fill the containers at the factory, and by using open means of transport to deliver the cement on site without any loss whatever. The containers are equipped with two slide rails, and rollers are mounted on the railway wagons, road lorries and transfer ramps to enable them to be quickly and easily loaded. Railway wagons, both standard and narrow gauge, motor lorries, funicular-railway cars and so on can easily be fitted with a suitable superstructure to facilitate the handling of the containers and to hold them fast after they have been moved into position. To provide for cableway transport two trunnions are fitted to the sides of the container and engage with the hooks of a bow suspended from the travelling carriage.

To explain more fully the sequence of operations we may take a typical example of this system as it is practised in Switzerland. In this instance the cement has to be transported from the factory first in standard-gauge rail cars, then in narrow-gauge cars, then by road lorry and finally by ropeway. As the quantities are substantial it has been found economical for the railway authorities to provide a special train which can be hauled independently of other transport operations. Assuming the train to be brought to the factory and already loaded with empty containers, it is shunted so that each wagon is successively brought underneath a loading hopper (Fig. 3) provided with eight electrically driven screw feeders which are automatically cut out when a predetermined quantity of cement has been filled into the corresponding number of containers. To prevent any loss or dust nuisance as the air is displaced by the falling cement, the loading is done under a closed system and the escaping air is drawn off by a vacuum hose which discharges into the top of the storage bins again. Although this equipment is somewhat complicated and expensive, it readily pays for itself in view of the economy it effects in time and labour, two attendants being able to load about 100 tons of cement per hour, this including the time taken to weigh the empty wagon and register the weight after it has been filled.

At the siding where the containers are transferred to the narrow-gauge trucks, two roller ramps are provided, one for the full containers and one for the empties. In order to obtain an easily negotiable slope there is a rising platform operated by oil pressure, which elevates the truck of full containers to a desirable level. The loaded standard-gauge train is now moved alongside the ramps and the full containers pushed off. This operation completed, the train is moved forward one truck length so that the empty containers from the second ramp can be loaded on to it. Both ramps are, of course, of such lengths and are erected at the appropriate interval

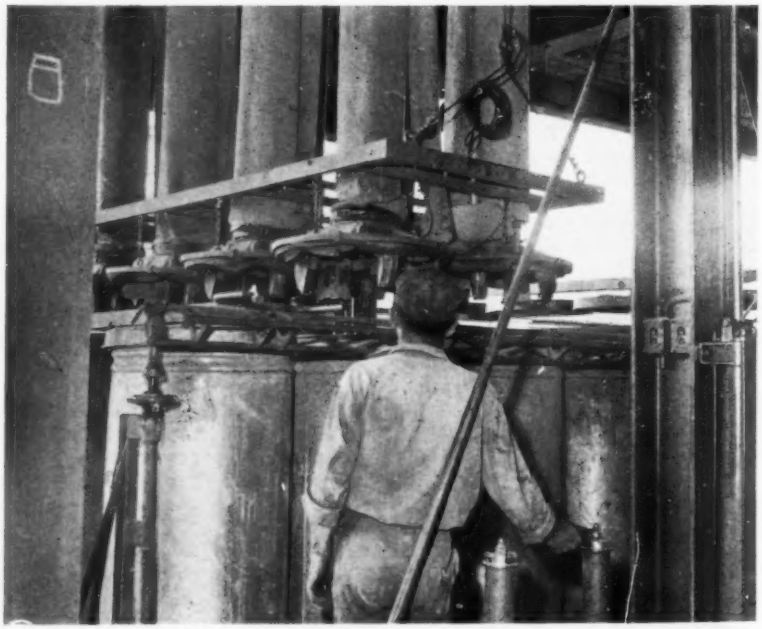


Fig. 3. A close-up view showing the method of filling containers, eight at a time, while on the railway wagons

* Transport Mécanisés

to enable the transfer of the full and empty containers to take place simultaneously, once the first full truck has been unloaded. As the springs of the loaded truck are depressed with the weight of the cement the levels are equalised by the oil-operated elevator, a slight pressure on a pedal enabling a very refined control to be obtained and the level of the ramp to be adjusted with great precision. With this equipment it is possible to transfer about 150 tons per hour without laborious effort.

Being of lower hauling capacity, the narrow-gauge railway train generally has to make several shuttle trips per day, and the ramps must consequently have sufficient capacity to enable a proportion of the containers to be stored on them so that the standard-gauge train need not delay its departure.

At the narrow-gauge terminus there are also two ramps, and the transfer of the full containers to the lorries is accomplished on similar lines to those already described. At the ropeway terminal the arrangements vary according to circumstances but obviously the storage ramps must be retained. Whether the containers are loaded on to the ropeway singly (Fig. 11) or on to cradles (Fig. 10) containing four or possibly more, depends on the local conditions. In any case the containers are taken from the ramps, possibly with the aid of a small industrial truck fitted with an elevating device, and brought to the cableway hitching-on point. Here the lifting device of the truck may be used to lower the trunnions of the containers on to the hooks of the suspension bow, or the containers may be automatically picked up by the travelling carriage as it is caused to ascend at an angle after being deviated downwards to enable the hooks to pass below the trunnions (Fig. 9). Whether the containers are transported singly or in multiples depends largely on the total quantity of cement to be handled and on the rate at which it is being used.

Fig. 6. A convoy of the special lorries carrying the containers

Fig. 4. Ramp for transferring the containers from railway wagons to lorries

Fig. 5. Container being transferred from ramp to lorry

At the upper end of the cableway the containers or the cradles, as the case may be, are automatically disengaged from the rope and pushed into a dustproof tippling compartment as shown in Fig. 12. On entering this compartment the door is automatically closed and the container inverted, discharging its contents into the storage bin, which is of sufficient capacity to provide against the usual contingencies. A suction device, connected with a filter, prevents any losses and inhibits any pos-

sibility of a dust nuisance. The emptying process, including the reattachment of the container to the ropeway, occupies a few seconds only and is effected by a single attendant.

It should be understood that equipment of this kind allows of almost infinite variations of application and great flexibility can be achieved. The outstanding advantages of the system lie in the total prevention of losses of any kind, in the labour economy to which it gives rise, the elimination of sheds and sacks, and in the superior organisation to which it lends itself, thus ensuring a steady and direct flow of material from the factory to the point of consumption.

To enable some estimate to be formed of the extent to which this system is being used, we give brief particulars of half-a-dozen current or recent schemes where the quantities of cement consumed range from 20-40 tons per day to 900 tons per day.

St. Barthelemy-Cleuson Dam. This dam is being built by the Western Switzerland Power Co. Ltd. (EOS) and involves the consumption of 75,000 tons (metric) of cement. This was required on the site at the rate of 380 tons per day and was supplied by the Roche, Jura-Wildegg and Holderbank cement factories. On the standard-gauge track the trains were made up of 20 railway trucks each equipped to carry 48 containers of 400 kg. (880 lb.) capacity. In this case it was possible to take the standard-gauge trucks right to the lower terminal of the ropeway, which was of the continuous two-way type having a capacity of 25 tons per hour. At the constructional site there were two tipping installations, provided with screw conveyors to discharge the cement into the storage bins.

Räthérichsboden Dam. The construction of this dam was recently completed by the Oberhasli Power Co. Ltd. of Innertkirchen, and required a total of 55,000 tons of cement at a daily rate of 360 tons, which was again supplied by several factories — Jura-Wildegg, Holderbank and Siggenthal. On the standard railway gauge the trains were made up of 19 freight cars each equipped, as before, to carry 48 containers of 880 lb. capacity. On this scheme a narrow-gauge railroad had to be used from Interlaken, where ramps had to be provided to accommodate 435 empty containers and a similar number of fulls. On the narrow gauge the trains consisted of seven flat trucks each adapted to carry 60 containers. At Innertkirchen the transport was taken over by eight diesel lorries equipped with super-

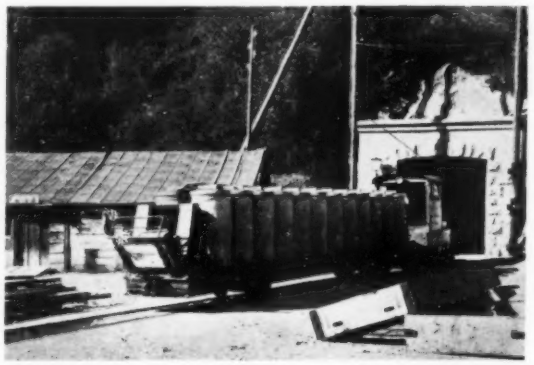


Fig. 8. Containers arriving at the site of Salanfe scheme, where 50,000 tons of cement is being handled

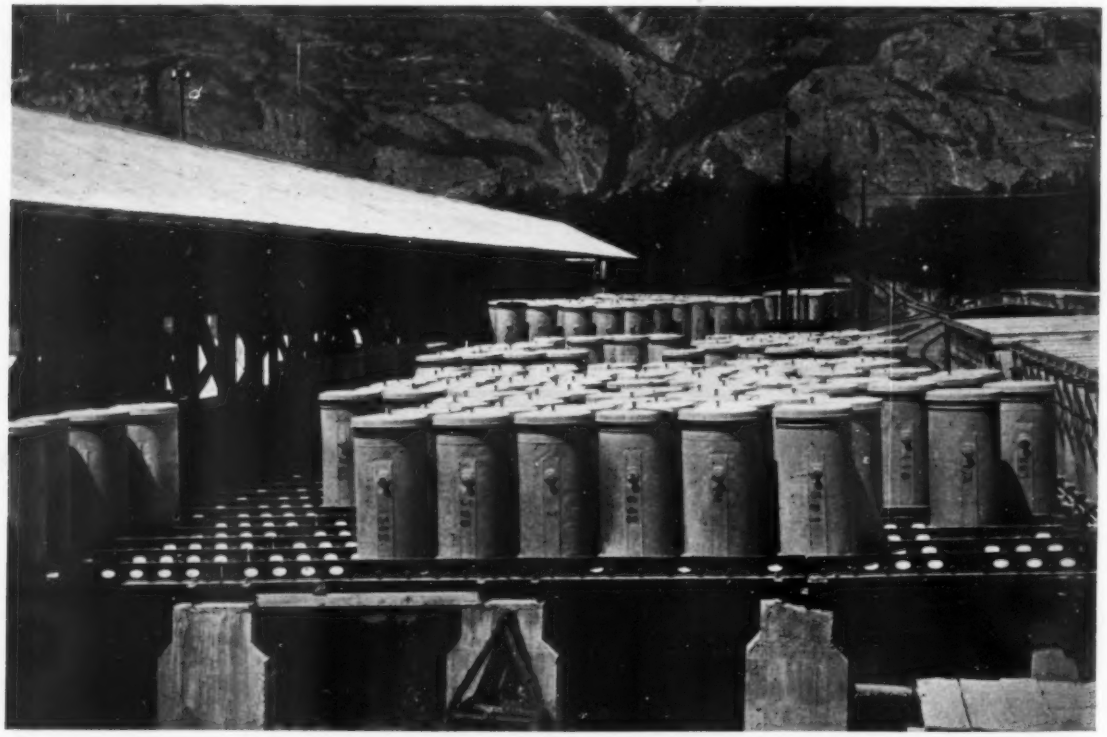


Fig. 7. The method of transferring containers from railway wagons to ropeway

structures to carry 15 containers each. Two tipplers were provided at the constructional site, the cement being taken to the bins by a bucket conveyor operating under a dust canopy.

Mattenalp-Gauli Dam. This comparatively small operation was also undertaken by the Oberhasli Power Co. Ltd. and involved the transportation of 5,000 tons of cement at the rate of 20-40 tons per day. Transfer from standard to narrow-gauge track was again involved, but a single diesel lorry, carrying 15 containers, sufficed for the road transport. The single-rope cableway (Fig. 10) was equipped with seven cradles each carrying four containers and a single tippler only was needed, discharging direct into the bin. At the transport point from the lorry to the cableway an industrial truck capable of handling four containers at a time was used.

Fig. 9. Transfer point where containers are automatically picked up as the travelling carriage descends down the ramp

Fig. 11. A 1,000 lb. container in transit on an aerial ropeway

Fig. 10. Ropeway for transporting containers in Gauli valley

Salanfe Dam. This dam, being built by Salanfe Limited of Lausanne, will require 50,000 tons of cement in daily quantities of 240 tons. In this instance the standard-gauge trucks are arranged in trains of 13, each truck carrying 48 containers. In this case one stage of the transport is effected by funicular railway which is installed in a tunnel, the trains consisting of seven trucks each carrying 24 containers. One tippler only is provided, a bucket conveyor and screw conveyors being installed to discharge the cement to either of two storage bins.

Oberaar Dam. This dam is another project of the Oberhasli Power Co. Ltd. and necessitates a total quantity of 100,000 tons of cement at a daily rate of 380 tons. This scheme also involves the transfer of the containers

Fig. 12. Dustproof tippler cabin for emptying containers

from standard to narrow-gauge railway to which end two full and two empty container ramps are provided each designed for 344 containers. The ropeway is of the continuous two-way type having a capacity of 20 tons per hour.

Grand Dixence Dam. The total quantity of cement called for by this immense project which is being built by Grand Dixence Limited of Lausanne is 315,000 tons for the first stage and no less than 1,100,000 tons for the completed scheme. A daily quota of 900 tons is being catered for, this being supplied by the Roche, Jura-Wildegg, Holdebank and other concerns. Every day two special trains each consisting of 23 Swiss Federal Railway trucks (type M-7) are required to transport the material. Fortunately neither narrow-gauge railway nor diesel lorry were needed as intermediaries as it was possible to connect the ropeway direct with the railway at Sion (Canton Valais). The rope transport consists of duplicate, continuous, two-way cableways, arranged in parallel, and each capable of carrying 50 tons per hour. At the construction site there are eight tipping installations equipped variously with screw conveyors and bucket elevators.

Mauvoisin Dam. This dam is being built by Electro-Watt Ltd. of Zurich and situated in the Canton Valais. It needs a total quantity of 600,000 tons of cement at a daily rate of 1,200 tons. A special standard-gauge railway line will be constructed from Sembrancher to Le Châble, to allow the standard-gauge trucks to travel up to this place, where the lower terminal of a continuous two-way type ropeway of 60 tons per hour capacity will be located. Three special trains of 20 freight cars each will arrive at Le Châble every day. Four ramps are needed to transfer the containers from the railway trucks to the ropeway. Each ropeway carriage is loaded with two containers. At the construction site there will be three tipping installations, but each will be arranged for handling two containers together, arriving by the same ropeway carriage. These tipplers will discharge either directly or by pneumatic means into five bins, having a total capacity of 5,000 tons.

Fig. 13. Storage silos, each of 1,000 tons capacity, serving the Rätherichsboden dam, Switzerland

Fig. 14. Grand Dixence scheme to which cement is being conveyed by containers at the rate of 900 tons per day; a total of 1,100,000 tons of cement is involved

In concluding these notes we are happy to acknowledge the assistance we received from T.M. Transport Mécanisés SA of Zurich, who kindly provided us with the photographs used for our illustrations and for the data relating to the various schemes we have mentioned.

Rawlplug Fixing Devices. A number of leaflets are to hand from the Rawlplug Co. Ltd. giving details of the wide variety of fixing devices which they have available for securing wiring, lighting fittings, pipes, switchgear and machinery to walls and floors constructed in brick, cement, concrete or masonry.

High-Speed Waterwheel Alternators

A paper by E. M. Johnson, M.Sc.Tech., M.I.E.E., and C. P. Holder, B.A., A.M.I.E.E. (both of Metropolitan-Vickers Electrical Co. Ltd.), was presented to the Supply Section of the Institution of Electrical Engineers recently, dealing with " The Design of High-Speed Salient-Pole A.C. Generators for Water Power Plants "

THE authors defined high-speed generators as those lying in the speed range of 300 to 1,000 r.p.m., with normal peripheral speeds of 15,000 ft. per min. and above, and runaway speeds of about twice that figure. The accompanying table shows a representative selection of machines of this type, either under construction or recently manufactured, in Great Britain, and the authors state that this table represents machines which are the largest yet built or projected at their particular speed.

Country of manufacture	Output	Normal speed	Peripheral speed at normal rotational speed	Runaway speed as a percentage of normal rotational speed
	MVA	r.p.m.	ft./min.	%
Canada* - England* -	122	327	16600	189
Switzerland* -	55	333	14400	198
England* - -	62·5	428	14250	182
Sweden* - -	66	428	16300	175
France* - -	80	428	16200	180
Switzerland* -	50	500	17300	184
Germany -	53	500	15400	172
England* - -	36	600	15570	182
Switzerland -	30	750	16200	184
Switzerland* -	60	750	16700	187
France - -	10	1000	15100	180

*Under construction

The authors stated that it was only at peripheral speeds in the region of 15,000 ft. per min. that stresses due to centrifugal forces began to have a determining effect on the design. Also below this speed the segmental type of rotor construction was excluded from consideration.

The rotor construction was usually determined by the peripheral speed of the generator at the maximum runaway speed of the turbine, which might vary considerably as between one installation and another, of otherwise similar type, due to the different maximum heads under which the turbines might have to operate. Typical runaway speeds were stated as being, for Pelton wheels 1·8 to 1·9 times normal speed, and for Francis turbines 2·0 to 2·2 times normal speed. Factors of safety for the rotor materials of the order of 1·5 at runaway speed, were generally employed.

Generators of the type under consideration might have rotor bodies up to 12 ft. 6 in. in diameter, and up to 15 ft. long. A characteristic of all designs was that the rotor body is subdivided—a design feature necessary not only to ensure homogeneous materials, but also to make transportation of the rotor body possible. The component parts might be made of rolled, forged or cast steel.

Solid poles, either cast or machined from the forging, were generally used, and had an advantage over the laminated pole, since they resulted in a more uniform distribution of centrifugal force along the length of the pole and rotor body.

The paper detailed a number of methods of attachment of the poles to the periphery of the rotor body, and gave the results of a number of tensile tests, including photo-elastic stress diagrams of a T-head type of design. It was stated that there was little to choose on the score of strength between the different methods of attaching the poles.

Regarding the field windings, the authors stated that present-day practice tended towards the fabrication of the large coils from straight lengths of copper without any bending. These lengths were punched to the correct shape in a press, and the joints were then brazed after assembly.

Asbestos was generally used for the insulation between turns of large field coils, and this material was sometimes combined with a small proportion of rubber. Insulation to earth was carried out in several ways, including the bonding of a spool of insulation, usually of mica with a cloth backing, to the inside of the coil and to insulating washers at the top and bottom.

Another method was to wrap micafolium around the pole body, consolidating the layers by ironing and heating in an oven using a shellac or similar bond. A third method was to use moulded insulation and flat insulating boards inserted between the pole body and the coil. The field coils were usually clamped by the use of steel, bronze or aluminium-alloy clamps secured by two or more bolts. The limits of core length and peripheral speed, beyond which field coil clamps become necessary, could be raised, in certain cases, by the use of wider copper for the coils.

Regarding damping windings, the authors stated that a low-resistance squirrel-cage damping winding was desirable for unbalanced rectifier loads, and also to give the maximum possible pull-in torque for resynchronising after a disturbance. It also reduced the transient overvoltages which might occur owing to an unbalanced short circuit, and which might otherwise contain dangerously high values, particularly if the generator was connected to a long transmission line.

For ventilation of the rotor, it was stated that an axial-flow fan, mounted at each end of the rotor, had special advantages in view of the considerable length of the core of salient-pole generators, of the type mentioned in the paper. The tips of the blades must be shrouded.

The stator frames of large high-speed generators were usually subdivided to facilitate transportation, or to permit removal of the rotor in a confined space.

Dealing with the core materials, the authors stated that although the large core loss on long machines had directed attention to the possibility of using low-

loss sheet steels, these materials, particularly where there was a pronounced grain orientation, were not found to be particularly suitable for rotating machines, since the principal flux paths were not unidirectional. Nevertheless, some of the new steels, with improved magnetic properties, were found to be suitable for waterwheel alternators, and the authors thought that a widespread adoption of an improved type of magnetic steel was likely when the materials became more readily available. The two-layer diamond type of stator winding in open stator slots, was generally adopted, and which had the merit of a low reactance, good cooling, identical interchangeable coils and not more than half the number of joints when compared with the concentric type of winding.

The authors discussed the insulation of the stator windings at some length, and mentioned that there were two main methods in use, the first being to wrap the slot portion with a number of layers of micafolium, extending several inches beyond the core at each end, and to insulate the rest of the coil with a varnished cloth or mica tape. The micafolium was preferably applied by the hot-iron process, and allowed to cool under pressure. The main drawback to this method was the joint between the cell and the tapping at each end of the coil. For this reason many manufacturers preferred a flexible varnished cloth tape for the end windings, although by so doing they committed themselves to Class A temperatures.

An alternative method was to tape the stator coil from end to end with a number of layers of mica tape. It provided a uniform Class B insulation and it facilitated the vacuum drying and the subsequent pressure impregnation of the coil with compound. A bituminous compound was usually preferred. The process of vacuum drying was followed, without breaking of the vacuum, by impregnation under pressure. Although it required elaborate factory equipment and was very costly this method was justified by the successful results obtained.

The bracing of the end windings to resist short-circuit forces became a matter of great importance when the forces tended to be large and when the coils had a wide pitch and an extensive overhang. In the largest machines the design of bracing tended towards steam-turbo-generator practice in the use of specially shaped non-magnetic supporting brackets to which both layers of the end windings were secured by insulated bolts.

The closed-circuit system of ventilation was generally preferred for large high-speed generators, the chief reasons being the reduction in noise and the exclusion of dirt from the stator windings and air ducts. The use of CO_2 fire-extinguishing equipment was also facilitated.

The paper emphasised that outputs considerably greater than those now attained by the use of machines of the design mentioned, were possible without radical departure from normal design. If aluminium were used for the field coils to lower the specific gravity of the windings, when compared with copper, it permitted an increase of about 20 per cent. in the rotor diameter with laminated poles, and of about 13 per cent. with solid poles. On the other hand, the lower conductivity of aluminium led to a loss of about 18 per cent. in specific output, but the gain in output due to increased diameter, and also to corresponding increased core length, more than offset this reduction. It was thought that machines up to 260 MVA at 450 r.p.m. were quite feasible, even with the restriction placed by transportation difficulties on the design of larger individual parts.

In the discussion, Professor M. G. Say mentioned that Continental and American manufacturers of water turbines had the immense advantage of a large market on their doorstep. British makers had to evolve designs which were suitable for the inevitably complicated transportation and handling operations which they would have to undergo before being installed in some remote site overseas. Mechanical considerations, in any event, would overshadow purely electrical considerations in high-speed machinery, since rotational forces rose alarmingly as the size, weight and speed increased. Centrifugal force would always dominate many aspects of the design.

Mr. J. B. Young, of The English Electric Company, stated that his firm were responsible for a 122 MVA, 327 r.p.m. generator mentioned in the paper, which represented a considerable advance in output at the speed. He stated that production and transportation limitations were usually accepted as causing the maximum rotor diameter to be about 12 ft. 6 in., but he had found it possible to go up to 13 ft. 9 in. in the case of the 122 MVA turbine.

Other speakers mentioned the possibility of hydrogen cooling for water-turbine alternators, and in the authors' reply, Mr. Holder said the only advantage of hydrogen cooling would be to reduce windage loss, since the size of these machines was usually determined by governing or system stability problems, and the other advantages of hydrogen cooling would not therefore be applicable.

Instrument Engineer. Vol. I, No. 1. April 1952. George Kent Limited, Luton, Beds. Price 2s. 6d.

The technique of instrumentation has made enormous strides within recent years, and this has resulted in the arrival of the engineer specialising in instrument work. This increased scope for instruments and control equipment has led George Kent Limited to commence publication of a journal known as *Instrument Engineer*, which will appear twice yearly and will be devoted to the needs of the professional engineer concerned with the installation and use of instruments and control equipment. The first issue contains articles on oxygen analysis, special-purpose applications of on-off control as applied to heat-treatment furnaces, the application of automatic control to a gas producer, and the history of flow measurement by differential pressure.

Transmission Towers for India. Blaw Knox Limited has received orders for the design of transmission towers for the Hirakud Dam Contract (66 kV) and the Damodar Valley Corporation (132 kV) line. These towers will be manufactured in India to the designs and detailed drawings supplied by Blaw Knox Limited. They will absorb approximately 12,000 tons of steel and the total value of the two contracts is approximately £700,000.

Electronic Computer for Canada. Ferranti Limited, the Manchester firm of electrical engineers who made the "Electronic Brain" which is installed in the University of Manchester, have now completed the second machine of a series which they are producing. It has been ordered by the National Research Council of Canada, and was shipped early in April to Toronto, where it will be erected in the University.

Fig. 1. Loch Beneyean at the new level, showing part of the road diversion to Glen Affric

The Glen Affric Scheme

The Mullardoch-Fasnakyle-Affric scheme has involved the construction of two dams, two tunnels, a main generating station at Fasnakyle, and a subsidiary underground station at Mullardoch. An unusual operation is being carried out at Mullardoch, where the height of the dam is being raised while the dam is actually under construction

PART ONE

THE North of Scotland Hydro-Electric Board's Mullardoch-Fasnakyle-Affric scheme, which is now in an advanced stage of construction, is expected to produce some 230 million kWh per annum from a catchment area of 124 square miles in Inverness-shire and Ross-shire, having an average annual rainfall of 107 in. One of the many points of interest in this scheme is the way in which it has been planned to preserve the amenities of the district. Glen Affric is one of Scotland's most famous beauty spots, and two earlier private-company's schemes, promulgated in 1928 and 1941 respectively, were successfully opposed. Both of these schemes proposed to convert Loch Affric and Loch Benevean, lying farther down Glen Affric, into one large sheet of water, which, in the opinion of many, would have ruined the beauty of the Glen.

In the scheme now under construction, Loch Benevean has been raised by only 23 ft.—a height that has left Loch Affric untouched—and the main storage is to be derived from Loch Mullardoch in Glen Cannich lying immediately to the north; this loch is being raised by 113 ft. and will carry the bulk of the fluctuations in storage. Thus the main inundation and the fluctuations in water level inseparable from such a scheme have been transferred from Glen Affric to the more remote Glen Cannich, to which, prior to the Board's activities, the only access had been by a rough cart track.

Before the level of Loch Benevean could be raised, the part of the road running alongside the river Affric and Loch Benevean had to be diverted and run at a higher level on the flank of the valley. The new road, which has wide open verges and several strong bridges, affords a much better prospect than did the road in the valley bed, and we gather that

Fig. 3. View looking downstream of the Mullardoch dam before ponding commenced, showing the two wings abutting on the central island

now that the level of the loch has been raised, some who were previously most doubtful of the effect of this scheme on the amenities are now commenting on the improvement in the scenic attractions of Loch Benevean. That this is no idle comment may be gathered from the glimpse of the loch which we reproduce in Fig. 1.

Another development brought about by the scheme has been the improvement of the road from the power station at Fasnakyle to the Benevean dam and the reconstruction of the ten-mile track from Cannich to Loch Mullardoch into a motor road. As reconstructed, these are single track with passing places.

Outline of the Scheme

Mullardoch dam, at the eastern end of the loch, is the biggest dam now under construction in the Board's area, and is 2,385 ft. long by 160 ft. high to deepest foundation. It will raise the loch level from 705 to 817 ft. O.D., and by converting Loch Mullardoch and Loch Lungard into one large sheet of water will provide a storage of 175,500 acre-feet.

From Loch Mullardoch to Loch Benevean a tunnel has been driven 5,738 yards long and of horseshoe section with an equivalent diameter of 15 ft. 9 in. Excavation is also in progress for a 2,400 kW underground station near the Mullardoch intake to make use of the difference in levels between the two lochs.

At Loch Benevean the dam is 582 ft. long and 125 ft. high, and has raised the level from 712 to 735 ft. O.D.

From Loch Benevean a main power tunnel extends a distance of 5,788 yards to a generating station, containing three 22,000 kW sets, at Fasnakyle on the north bank of the river Glass. This tunnel is in three sections—a low-pressure section 4,113 yards long, of horseshoe section and of 14 ft. 6 in. equivalent diameter, a high-pressure circular section 1,408 yards long and 14 ft. 6 in. diameter, which trifurcates near the power-station into three steel-lined tunnels each 8 ft. 4 in. in diameter and 800 ft. long. The low-pressure and high-pressure tunnels are connected by a 341 ft. vertical shaft which continues upwards for a further 150 ft. to form a 45 ft. diameter surge shaft.

Preliminary works for the scheme were on a large scale, and in addition to the road improvement and diversion already mentioned, involved the building of two labour camps and a temporary generating station. The main labour camp was situated at the village of Cannich, in Strathglass, and provided accommodation for 1,400 men. A subsidiary camp at Cosac near the Mullardoch dam houses a further 700 men. The temporary power station was also located at Cannich and consisted of six 600 kW 11,000 V Mirrless/Bruce-Peebles diesel-alternator sets feeding two 11,000 V transmission lines serving the working sites in the two glens. Subsequently these lines were fed from Beauly substation via Kiltarlity, the supply being stepped down from 33,000 V, and the temporary station shut down. The capacity of the Cannich station has been reduced to 1,200 kW and is used as a standby.

Mullardoch Dam

Upstream and downstream views of Mullardoch dam appear in Figs. 3 and 4, and a general arrangement drawing is given in Fig. 2. At this point the watercourse is divided into two branches separated by a central island, and the dam has accordingly been built in two wings inclined to one another and each having an abutment on the island.

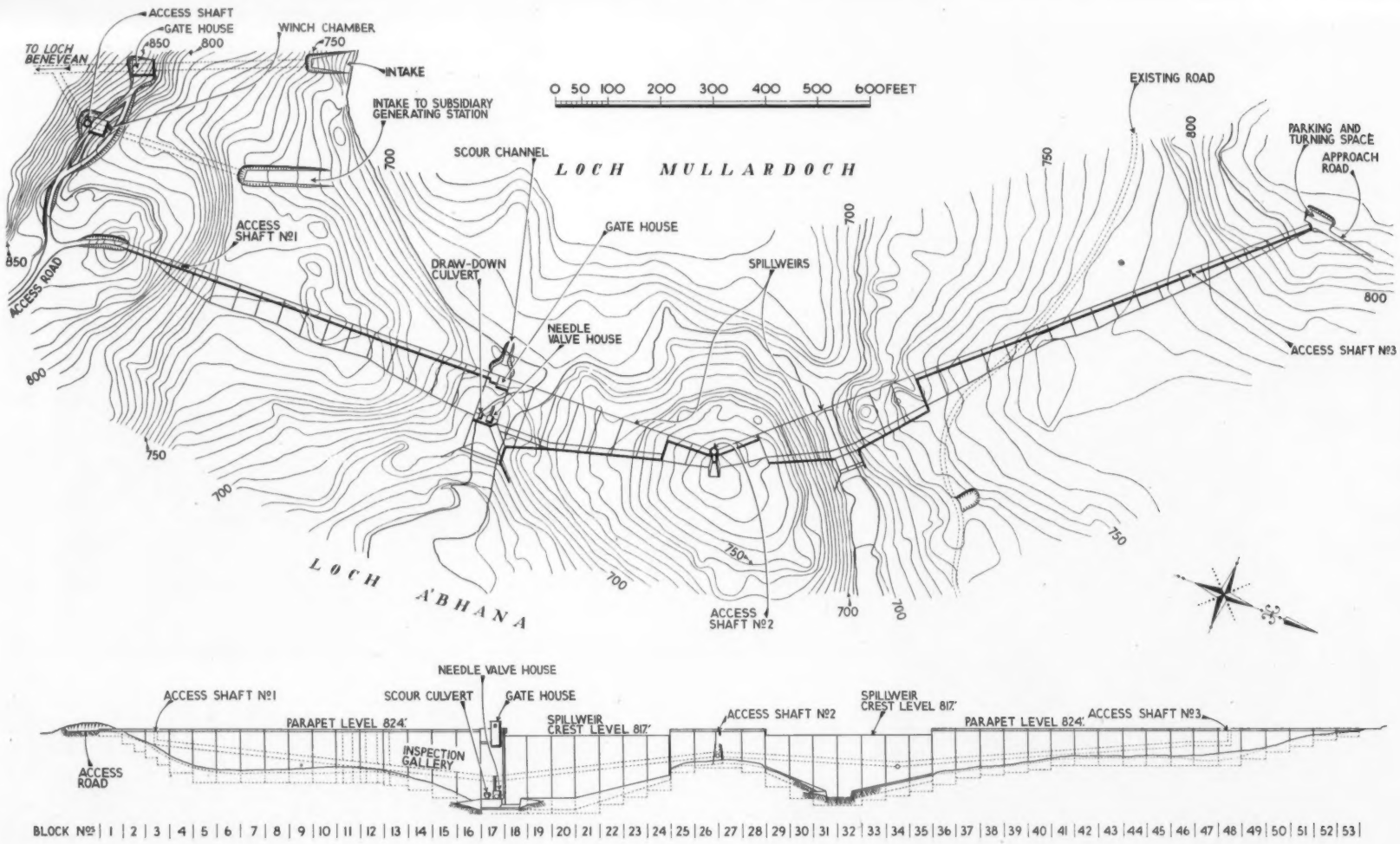

ACCESS SHAFT
GATE HOUSE
WINCH CHAMBER
TO LOCH BENEVEAN
INTAKE
INTAKE TO SUBSIDIARY GENERATING STATION
0 50 100 200 300 400 500 600FEET
EXISTING ROAD
PARKING AND TURNING SPACE
APPROACH ROAD
SCOUR CHANNEL
LOCH MULLARDOCH
ACCESS SHAFT Nº1
GATE HOUSE
DRAW-DOWN CULVERT
SPILLWEIRS
ACCESS ROAD
NEEDLE VALVE HOUSE
ACCESS SHAFT Nº3
LOCH A'BHANA
ACCESS SHAFT Nº2
NEEDLE VALVE HOUSE
ACCESS SHAFT Nº1
SCOUR CULVERT
GATE HOUSE
SPILLWEIR CREST LEVEL 817'
ACCESS SHAFT Nº2
SPILLWEIR CREST LEVEL 817'
PARAPET LEVEL 824'
ACCESS SHAFT Nº3
PARAPET LEVEL 824'
INSPECTION GALLERY
ACCESS ROAD
BLOCK Nº 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53

Fig. 2. Plan and elevation of Mullardoch dam, showing the location of the tunnel intake and of the subsidiary generating station

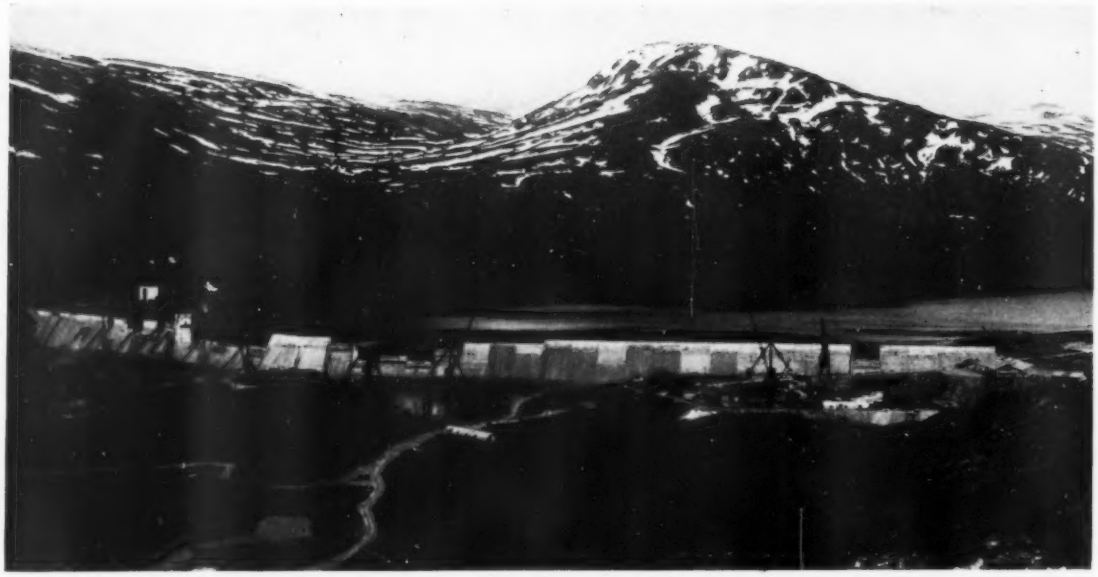


Fig. 4. View of the Mullardoch dam looking upstream, taken after ponding had commenced

Each wing has a spillway 315 ft. wide, and the south wing (on the right-hand flank) is equipped with a needle valve and scour culvert. The dam is of the mass-concrete gravity type and is about 100 ft. thick at the base; it has involved the excavation of some 113,000 cu. yards of rock to payment lines, and will contain 309,900 cu. yards of concrete.

The design of the spillweirs and spillway channels was determined by model tests. Both spillweirs are considerably wider than the watercourses into which they discharge, and the problem was to secure that the water discharged centrally into the watercourse with its excess energy dissipated. This was complicated by the fact that the spillways are not disposed symmetrically about the watercourse. Steps and horizontal sections have been introduced where required into the spillway channels to prevent the downcoming water from leaping over the retaining wall and to regulate the flow into the respective stilling pools. The toe of each spillway is faced with basalt ashlar pitching.

No particular difficulties were encountered in preparing the dam site, which consisted of a rock bed overlain by some moraine and a thin layer of peat. The cut-off trench ranged from 6 to 12 ft. deep except at the outfalls, where the depth was increased as found necessary. The trench was 5 ft. wide at the bottom and was given a batter of 1 in 4. Grouting holes, 3 ft. apart, were sunk from the bottom of the trench to a depth of 20 ft., and grouted at pressures ranging from 40 to 100 lb. per sq. in. In two areas where the rock was of poor quality, a second grouting stage was included, 40 ft. holes being driven between the 20 ft. holes and grouted at pressures up to 100 lb. per sq. in. Two 40 ft. holes in each 45 ft. block were tested for leakage prior to grouting.

Aggregate for the dam is being obtained from a quarry about three-quarters of a mile downstream of the site on the northern flank of the glen. The rock, a psammitic schist, is crushed in a Cedar Rapids

Fig. 5. Mullardoch dam, south spillway stilling-pool section, showing the Bailey bridge carrying the rails for the concrete trolleys

portable crusher and graded to $2\frac{1}{2}$-$1\frac{1}{2}$ in., $1\frac{1}{2}$-$\frac{3}{4}$ in. and $\frac{3}{4}$-$\frac{3}{16}$ in., in which form it is conveyed by an aerial ropeway to the storage silos of the batching and mixing plant, which is located at the northern end of the dam site. Sand procured from a local deposit upstream of the site is carried by the same ropeway, and cement is brought by ship to Inverness and thence by road.

The mixing plant consists of three Stothert & Pitt 1 cu. yard mixers discharging into bottom-opening skips of 2 cu. yard capacity. These skips are carried in pairs on trolleys running on a 2 ft. gauge track, and rakes of one or two trolleys are taken to site by Hudson and Simplex diesel locomotives.

One of the valuable inventions of the last war was the Bailey bridge, and we were particularly interested to find a Bailey bridge in use to carry the concrete trolleys along the dam site. As will be seen from Fig. 5, this bridge spans the site immediately on the downstream side, and carries a double line of rails. Eight electric derricks are disposed at intervals along the site to transfer the concrete skips from the bridge to the dam, and there is also a travelling electric derrick and a steam derrick.

Fig. 6. Two of the blocks in the south wing being carried up at reduced height

For purposes of construction the dam has been divided into 53 blocks, each 45 ft. wide, with copper sealing joints between blocks. Each block is divided into three 15 ft. panels, and the concrete is laid in 4 ft. lifts and vibrated. Climbing shuttering designed by Cyril Parry is used, as seen in Fig. 6. It consists of wooden shutters in 7 ft. 6 in. widths carried on steel soldiers, the soldiers being secured by two lines of bolts screwed into nuts sunk in the concrete at vertical centre distances corresponding to the lift. At the top of each soldier a placer bolt carries the nut to be sunk in the next lift, and when the shuttering is struck it is moved up a distance corresponding to one line of bolts. Thus each line of bolts is first set in position, then used as the upper fixing for

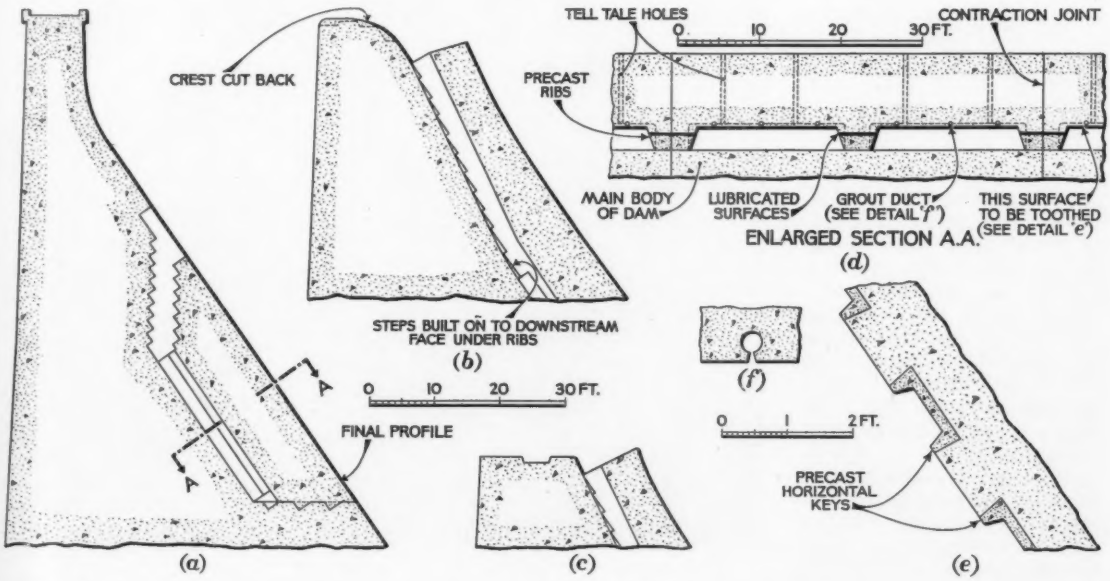


Fig. 7. Details of the construction adopted to raise the height of the dam by 20 ft. while under construction

the shuttering, and finally as the lower fixing.

Seeing that there are two water channels at the dam site it was an easy matter to close the dam. A cofferdam was first placed across the north channel, and all blocks in this region were built up except one, which was left low to pass the river water when the cofferdam was removed. After this had been done a second cofferdam was built across the south channel and all the blocks in that section built up, including that carrying the culverts. This cofferdam was then removed and the water passed through the culverts; the north cofferdam was then replaced and the low block brought up. The dam was finally closed by shutting off the culverts.

One culvert is fitted with a Glenfield & Kennedy 72 in. to 60 in. needle valve with jet disperser at the downstream end and with a 6 ft. span by 7 ft. 3 in. deep free rolling emergency gate at the upstream end, with electric hoisting gear, by the same makers. The other culvert is intended only to maintain a clear waterway when the loch is empty, and has a single-faced sluice on the upstream end and a hinged blank flange on the downstream end. To prevent the opening of this culvert while the loch is full, the sluice control spindle terminates at a point 20 ft. up the face of the dam so that it cannot be reached until the water has been drawn down. Compensation water is tapped off from the first culvert upstream of the needle valve, and is controlled by a 6 in. hand - operated regulating valve.

Changing the Height of the Dam

An engineering operation involving changing the height of part of a dam while it is actually under construction must surely be unique in the annals of dam building. This interesting operation is taking place at Mullardoch, and arose not through engineering considerations but because of a cut imposed in capital expenditure. To effect this it was decided in 1950 to reduce the projected height of the southern half of the dam by 20 ft. This involved a step-back on the downstream side of each block at the height it had reached on the date of the change (see Fig. 6). In 1951 it was found possible to review the position and take advantage of the presence of contractor's plant to go ahead with the whole of the dam to the full height. Nevertheless, this involved some tricky problems, for the blocks, which presented an assortment of heights and step-back levels, had all to be brought to the full thickness in such a manner that the design strength appropriate to the greater height was secured. This was complicated by the fact that the shortage of steel prevented the use of reinforcement.

Although a general procedure was adopted for laying the backing concrete, the exact method of treatment for the various blocks differed according to the heights to which they had been taken. Drawings of the arrangements are given in Fig. 7 and views of the work are reproduced in Figs. 8 and 9. Blocks that were some way off completion (at the reduced height) were carried up with the downstream face vertical until the profile appropriate to the increased height was reached, the top of the block then being completed to profile. On the vertical portion of the downstream face a system of toothing was formed to engage the backing concrete, as shown in Figs. 7 *a* and 9. This treatment would not have been appropriate for blocks that were nearly or fully completed to the reduced height, and in these cases the top was cut back as indicated in Fig. 7 *b* and *c*. Toothing was also cut in the horizontal faces of the step-backs left by the previous reduction in dam height, as shown in Fig. 7 *a*.

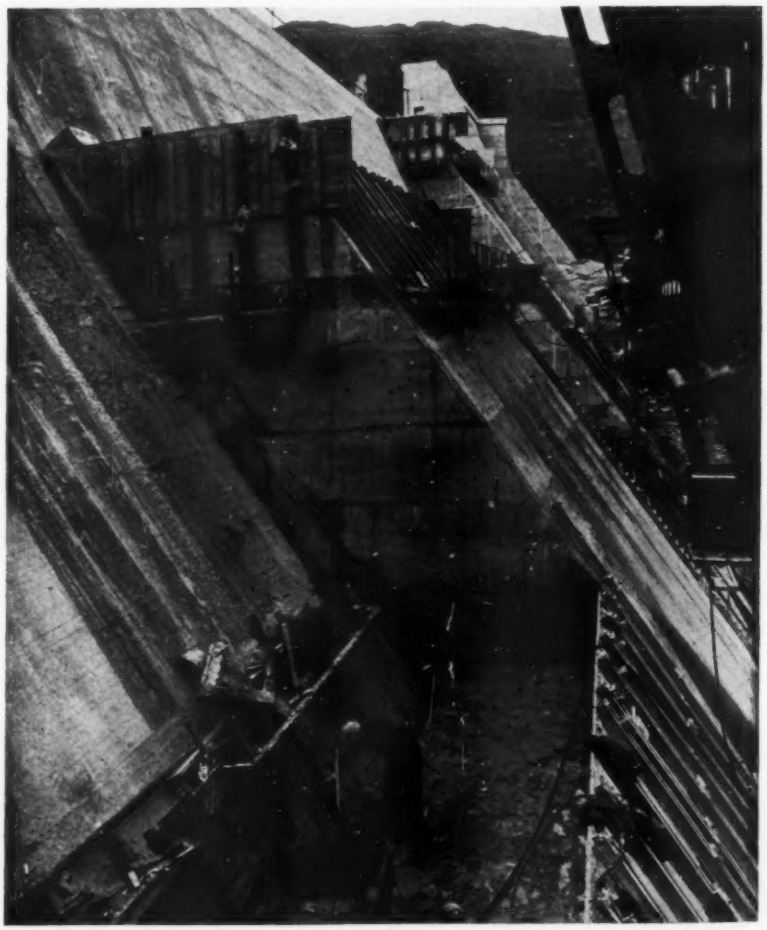


Fig. 8. Backing concrete being carried up to bring the blocks to full thickness. The shuttering for the slots in the backing concrete is being set on the block in the foreground

Fig. 9. Blocks 16 and 17 carried up to full height with a vertical downstream face provided with toothing to engage the backing concrete

The problem in designing the backing concrete was, of course, to circumvent the effects of the contraction of the new concrete in relation to the old. It was therefore decided to place the backing concrete in the form of sliding slabs, leaving slots between these slabs and the former face of the dam, which could be filled in when contraction had ceased. Two slots were formed in the backing concrete for each block, 19 ft. wide, 3 ft. deep, and extending from top to bottom of the backing slab. An access gallery at step-back level was left at the bottom of each slab.

To design shuttering for these slots that could have been struck easily in this confined space would have been awkward if the slab were made as a monolith, but the difficulty was surmounted by making a series of precast ribs to form the sides of the slots. The arrangement is shown in the section, Fig. 7 *d*, and in Fig. 8 can be seen the slot shuttering for the block in the foreground and the precast ribs for the adjacent block. Two layers of building paper with an intervening layer of grease were laid between the precast ribs and the backing concrete to enable the latter to slide freely when contracting. Horizontal keys (Fig. 7 *e*) were also laid to form a system of toothing on the inner face of the backing slab. In the case of blocks on which a vertical toothed face had been formed, a corresponding face was formed on the backing slab at a distance of 3 ft. Grouting channels were left in the faces of the backing slabs, and the portions of the dam face included in the slots were thoroughly scabbled.

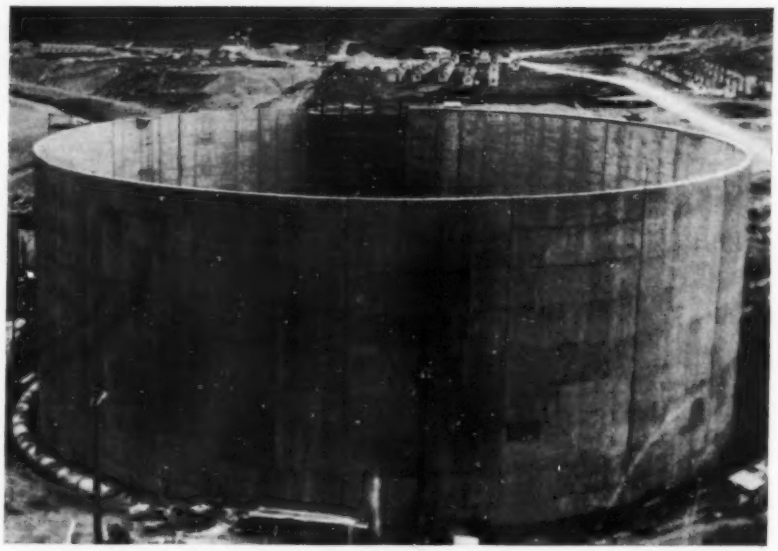
At the time of our visit the backing slabs were in course of construction, and experiments were in hand on the use of Colcrete as a filling for the slots. This system, which has been developed by Colcrete Limited, Strood, Kent, depends upon the production of a colloidal grout which is stable but highly fluent and can be injected into a prelaid aggregate. In an ordinary grout the wetting of the surfaces of the cement grains by the water is never complete, but in the Colcrete machine the mixture is pumped at high speed through a narrow gap so that a fluid with some colloidal characteristics results. In a second stage this fluid is mixed at high speed with a desired proportion of sand, giving a grout possessing the properties of stability and exceptional fluidity to which we have referred. No chemical constituent is required to produce the grout, high-speed mechanical mixing being the only means employed. This grout is stated to be water repellent, enabling it to be used for underwater work, to fill all voids and fissures completely, and to make a perfect bond with either wet or dry aggregate. When set, it is claimed to be impermeable to water and to provide a certain and thorough key with the surrounding structures.

The aggregate, from which all material below 1½ in. must be excluded, is placed in position independently, and the grout is either poured over it and allowed to penetrate downwards, or introduced near the bottom through grouting pipes or channels and allowed to fill upwards. This method ensures that the aggregate has point contact in all directions. The voidage is therefore less, and proportionately less grout, and therefore less cement, is required to fill it; thermal stresses are reduced, and cumulative contraction is prevented. There are also practical advantages in that the aggregate is not passed through the mixer, which need only be large enough to mix the grout, and the cost of handling the aggregate is less. In frosty weather work need not be stopped because the placing of aggregate can proceed.

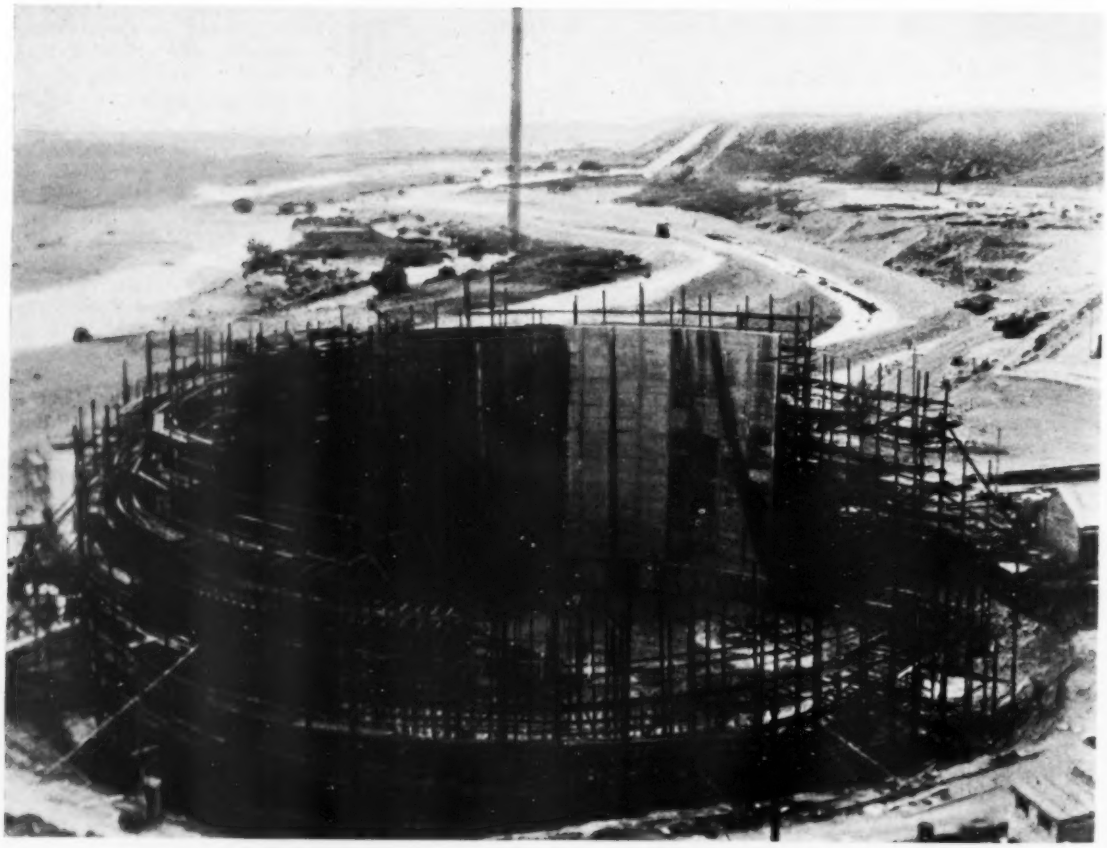
(Continued on page 195)

New Zealand Hydro-Electric Feat

Among projects for the expansion of hydro-electric power in New Zealand, the scheme for harnessing waters from Lake Tekapo, in the heart of the South Island, is notable for its huge surge chamber, which has been built at the end of a mile-long tunnel bringing water from the lake. This surge chamber is the largest in the Southern Hemisphere. With a capacity of 7,000,000 gallons, it is 60 ft. high and 160 ft. in diameter. About 500 tons of reinforcing steel and 8,000 tons of concrete were used in its construction. The concrete was poured into a form of shuttering, held by radial supports, which is considered unique.



The completed surge chamber at Lake Tekapo. It is built in 19 sections, each 25 ft. wide, and the walls are about 2 ft. thick at the base, tapering back on the inside to about 1 ft. thick



The surge chamber under construction. The picture shows four completed sections, each built by a process of continuous pouring of concrete. Special dynamometers were placed at intervals in the shuttering walls to enable the pressure of concrete on the walls to be regulated

Water Power in Africa

The substance of a lecture recently given at Imperial College, London, by Professor Frank Debenham, late Professor of Geography at the University of Cambridge

THE most surprising fact about water power in Africa is the very high potential and the very low utilisation; that is to say, it is surprising until one begins to enquire why it should be so.

Although potential hydro-power is rarely a figure on which to base plans it can be used for a general comparison of the resources of one country with another. A fairly recent assessment of such resources taken by continents is that North America, South America, and Europe each possess rather more than 10 per cent. of the world's total and Asia about 22 per cent. Africa soars into the lead with over 40 per cent. The reason is, of course, that Africa has an enormous area of plateau country just where heavy tropical rainfall is experienced, and water-power potential is practically nothing more than the product of the rainfall available and the height above sea level at which it reaches the ground.

The figure is even more astonishing if we strike out, as we must, almost the whole of the Sahara and an area in the south-west, including the Kalahari, which has no surface flow of water. Analysis of where this high potential is most concentrated reveals another extraordinary fact, namely that most of it, indeed nearly one quarter of the world's potential water power, is in the basin of the Congo river, which is only one-tenth part of Africa.

If we pursue these world figures a little further we find that while the other continents taken together are using rather more than 10 per cent. of their available water power, Africa is at present using only about one-half of 1 per cent. It would seem, therefore, that while to the hydro engineer Africa may be a dream it has never yet appealed very much to the promoter of hydro-power schemes.

Again the reasons are not far to seek. As compared with the three northern hemisphere continents, Africa lacks several of the prerequisites of power production. One is capital, of course, but that is of much less importance than the others because capital is mobile; it can be moved from one part of the world to another at the scribbling of a pen. A more serious lack is that of communications, including seaports, navigable rivers and easy gradients—and indeed this is the price Africa has to pay for its high water-power potential. This may be taken in conjunction with another significant deficiency, that of fuel—oil and coal; for, as we know, water power alone cannot cope with a comprehensive range of industry. A certain paucity of raw materials on the spot must be added, of course, at present. Again, as compared with the northern continents there is a serious shortage of labour, as to both quantity and quality.

Some, perhaps all, of these difficulties will be surmounted in time, but they all help to explain that miserable half of 1 per cent. usage of water power, which indeed is nearly all concentrated at the two ends of the continent, the Mediterranean border and the Union of South Africa. And that leads us to the greatest lack of all, in Central and East Africa at all events, and that is Europeans.

The plain, unvarnished fact is that the world's water power has depended almost entirely upon Europeans (including the transplanted Europeans of North America) for its development. This has been so until recently even in Asia, in spite of the high intelligence of the Indians and the Chinese. China, it is true, was probably the first country to use water as a form of power, but she never got far beyond the simple water-wheel and peasant engineering.

If the Asiatic has been slow to appreciate what can be done with falling water how much less can we expect of the African, who has only recently been introduced to the wheel and still does not quite understand it? To us a symmetrical mass revolving on an axis is one of the simplest of mechanical contrivances, but there are parts of Africa where it is still little short of magic. Not long ago I was in a fairly wild part of the Kalahari with a lorry and we had jacked up one wheel to repair the brake drum. The local Bushmen, still at the bow-and-poisoned-arrow stage, have now seen a few lorries or ox-wagons and doubtless think of their wheels as a sort of roller. Some of them were watching the operation and when the mechanic (a Bechuana, by the way) turned the wheel with a sudden thrust there were loud "wows" or equivalent expressions of surprise from the little brown men. With the help of the interpreter I learned that they expected the wheel to "run away" when it was turned. That it stayed in the same place while turning was obviously beyond all reasonable understanding.

The Bantu will, however, become wheel-minded, and already make fairly competent mechanics, but it is a far cry from that stage to design and planning.

We must not labour the point that only Europeans are able to develop the hydro-power of Africa or we shall be accused of introducing politics. Nevertheless it would be well if some of those who decry European settlement in Africa were to realise that for a long time to come only the European can raise Africa out of its present situation, which, put quite bluntly, is that of a continent producing barely enough food for itself and making little or no contribution to world economics except by minerals—a wasting asset.

Let us now turn from these general considerations to a view of immediate prospects for water power in this backward continent. Of big schemes of development there is no lack, on paper, and some have got well beyond the paper stage. As far as East Africa is concerned the Owen Falls scheme takes pride of place. It is one of those schemes, not common in Africa, where the use of water can be made in the right sequence, that is to say, where the irrigation value of the water comes after it has yielded its power. It is a very extreme case of the right sequence, however, since the irrigation area is nearly 2,000 miles

from the power area. It is also unique in that nature has provided the reservoir in a vast shallow lake of which if necessary almost all the water could be used. This is in strong contrast to the other large lakes, such as Nyasa and Tanganyika, whose even greater volume is taken by the amateur to be of similar potential. In both those lakes only the uppermost layer, measured by feet only, can be used for power, and neither of them supplies a useful head of water in the vicinity as does lake Victoria.

We must go a long way south before we meet the next big scheme that has some prospect of development in the near future, though we can note that the great Rufiji river and its tributary the Ruaha of Tanganyika Territory have the necessary characteristics of rapid fall from a highland of good rainfall.

The Zambesi is an attractive river to the power engineer, though he is warned off, on aesthetic grounds, from the magnificent Victoria Falls. In due course a less spectacular series of falls, the Kebrabasa Rapids of Portuguese East Africa, may attract attention, but at the moment the most prominent project is one where there is hardly any natural fall, namely, the Kariba Gorge scheme, fostered by Southern Rhodesia but actually sited on its boundary with Northern Rhodesia.

This is one of those curious cases where the excellence of the site as to foundations, width of gorge, throwback, etc., goes far to outweigh considerations of other kinds, such as proximity to industry and combination with irrigation lower down. Thorough surveys have been made already, and the fact that an enormous lake would be created must be admitted as a factor in the discussion as to whether it is a sound scheme or not. Even the matter-of-fact engineer must be stirred by the idea of an artificial lake at least 100 miles long, and it is natural to find support from the patriotic and energetic white population of Southern Rhodesia.

As a purely engineering proposition it suffers somewhat by comparison with a neighbouring scheme, that of the Kafue Gorge, only about 50 miles to the north of the Kariba. Here there is perhaps only one-sixth of the discharge of the Zambesi, but that is counterbalanced by an actual fall in level of at least 1,500 ft., of which about 1,000 ft. seems to occur in about 10 miles. If the Kariba Gorge is rather hard to reach then the Kafue Gorge almost deserves the adjective inaccessible, though engineers quite rightly refuse to recognise such a word in connection with power schemes. I have had the good fortune to fly down it, an exciting trip since it was then quite unmapped, and can testify to the outward appearance of power in a succession of foaming rapids over at least seven miles. The scheme is in the wrong sequence, however, because only 20 miles above the mouth of the Gorge there is the lower end of that magnificent area, known as the Kafue Flats, 150 miles in length and subject to annual floods, where a sort of natural irrigation for grassland could be turned into controlled irrigation of crops and pasture without any great difficulty.

It seems possible that this awkward sequence need not ruin the power scheme, however, because the reservoir and regulator for both irrigation and power could be put at the upper end of the Flats, at a place which hardly deserves the fine-sounding name of the Meshi-Teshi Gorge, but where the topography is promising for a barrage. This regulator may even be supplemented by others higher up, notably at the Lukanga Swamp, which is at present acting as a natural regulator to the flow of the Kafue.

It is then a matter of adjusting the claims of power and irrigation. It may be noted that in both these schemes the possible markets for the power are at a considerable distance, so that transmission costs will be high, and there are as yet no natural centres of an industrial population within 100 miles, or indeed centres for growing their food except the Kafue Flats.

Finally we may mention a fourth scheme, still at an immature stage, but possessing the right sequence, and that is on the Lower Shire river in Nyasaland—the river which issues from lake Nyasa, and after some 50 miles descends about 1,000 ft. in a series of rapids and falls known as the Murchison Rapids, covering perhaps 25 miles or more of its course. The scheme is in the right sequence as below the rapids comes the Lower Shire flood-plain, an area about 60 miles long and averaging 10 miles in breadth which already grows cotton and has promise for sugar and other crops.

Moreover, Nyasaland is the most populous of the Central African territories and at present has to permit a high proportion of its male labour to migrate to Southern Rhodesia and the Union to find work. Though the power would be produced at only a few hundred feet above sea level in somewhat unhealthy surroundings, it need only be transmitted 20 miles or so to the thoroughly healthy Shire Highlands, 4,000 ft. above sea level.

The real difficulty here is the curious one that in the past the overflow from the lake has undergone a cyclical variation whereby for a few years there was even no overflow at all. It is now generally agreed, I believe, that this variation was not primarily due to rainfall or indeed to any truly cyclical factor but to blockages by silt and vegetation which in the natural state are in fact periodic. Until the lake level is regulated, not in itself a very difficult matter, there can be no scheme for the use of the power in the Murchison Rapids.

Lack of space compels us to skip over the moderate-sized schemes for power, such as that of the Mulungushi Gorge in Northern Rhodesia, and turn to much smaller schemes which might be termed settler-size. There seem to be two reasons why the European settler has hitherto been slow in availing himself of water power. One is that he tends to settle near the railway, which runs along the divide, and the other is that for crops there is little use for power. Hydraulic rams are coming into favour but there again the seasonal character of the rainfall means that there must be considerable expense in building conservation works. We can perhaps leave the European to work out his own salvation as to local power for his needs and turn to the African. Has he any use for water power, and if so how can we help him to it? The answer is not encouraging at present, but that need not deter us.

The main expenditure of energy in an African village (apart from cultivating by the hoe) is the grinding of the meal. Now this is entirely the woman's job, and a prodigious amount of energy she spends in pounding up the meal and sieving it for the daily meals, in troughs or deep wooden mortars with a small pole as pestle. But tradition is much against any rapid change, the chief will say that it keeps the women occupied, and even the women themselves will say they are accustomed to it and do not want a

change. On the other hand, most villages are some way down the slopes from the divide and on streams which either are already perennial or could be made so. Also, in spite of his being new to the wheel and still newer to anything approaching gears, the African could understand the simple overshot wheel such as our medieval corn mills had as their early models.

I believe that the change will be gradual and that it will not come through individuals, in spite of the fact that every village will have an odd man or so back from the mines or the railways who can appreciate power and a quicker way to wealth by its use. I would suggest that it will come rather through the village councils, which are now just beginning to appreciate their powers and their financial resources. Sooner or later these councils will learn that bringing water to the village by a furrow and fluming, both for power and water supply, are not white man's magic and that in the end it would enable them and their womenfolk to have more spare time for production of food or cash-crops.

At present the water engineer in Africa is fully occupied with conservation projects, but he will in time be able to educate the African to the concept of water power and it may well be via the simple overshot, geared to a mill of some kind, as we still have it in England.

Yet, even when we allow for the backwardness of the African and the fact that Europeans are thin on the ground, we find a curious lag between the need for hydro power and its development. Now this is almost entirely due to our lack of information about the regime of the rivers over a reasonable period of years. The engineer in Africa is still at the reconnaissance stage, when he is primarily a hydrologist studying the water resources rather than a hydraulics engineer putting them to work. It is an interesting stage but not a productive one; yet we should note that it should employ a whole range of experts, not merely the engineer, since now is the time for what we may call the T.V.A. approach. The Tennessee Valley Authority was given powers to plan every single activity and use every resource in its valley, not merely those directly associated with the rivers. We cannot provide the capital of a T.V.A. nor can we give the wide authority, since international boundaries interfere, but we can try to study the whole needs of a river basin and ensure a harmony between the many activities to which it is suited. I believe that this is being done in a general way for the Kafue in Northern Rhodesia, but there are many other major river valleys where a Commission with wide powers and covering a broad field of experience could avoid the mistakes of piecemeal development and secure a balanced economy.

What are the special difficulties in hydro-power engineering in Africa as compared with those of temperate countries, apart from those common to all the tropics such as the incidence of disease? Perhaps the chief ones are thunderstorms and swamp vegetation. Of the first we need only remark that in a country where 10 in. of rainfall may fall within 24 hours none of the ordinary safety factors for spillways, structures, etc., can apply. The engineer can cope with floods, however, because he can measure them and take his precautions. With vegetation it is different, because ecology has not yet taken a full measure of what aquatic vegetation in the tropics can do. We know that it helps the water engineer in one direction, since it is the vegetation that produces the countless plateau swamps of Africa which delay the run-off. In other ways it is bound to hinder him, as for instance in blocking the outlet of lake Nyasa for a number of years. What it will do when we come to running long canals across country has still to be found out. The moral is that a hydrologist in Africa must either be an ecologist as well or make sure that he takes one.

In summing up, we may say that although there must be a big future for water power in Africa we must never forget that Africa cannot be hurried.

Allis-Chalmers Annual Review

The 1951 Annual Review of the Allis-Chalmers Manufacturing Company, Milwaukee, is the 105th of the series, and records some notable hydro-electric contracts. Two units shipped to Hoover dam, comprising 115,000 h.p. 480 ft. head Francis turbines coupled to 82,500 kVA 180 r.p.m. generators, are claimed to be the largest complete units ever built by one company. Pickwick Landing plant received two more 55,000 h.p. Kaplan units, bringing the total to six. These are stated to be the largest Kaplans in physical size in the United States, the runners being 24 ft. 4 in. in diameter. Other important shipments included the sixth 20,000 h.p. Francis turbine for Grand River Dam Authority, the remaining three of four 105,000 h.p. units for Hungry Horse dam, and the fourth 62,500 h.p. turbine for Bull Shoals.

The first reversible turbine unit for installation in the United States has been ordered by the U.S. Bureau of Reclamation for their Flatiron plant. As a motor-and-pump unit, the set will deliver 370 cusecs against 240 ft. head, and as a turbine-and-generator unit 10,000 kVA at 13,800 V.

Canadian Allis-Chalmers (1951) Ltd. is to build a 150,000 h.p. 2,500 ft. head 377 r.p.m. vertical four-jet impulse turbine for a plant in British Columbia. This plant will establish a capacity record when the 16 units contemplated are ultimately installed. The operating head will be the highest in the two American continents and the impulse wheels are believed to be the most powerful in the world.

From page 191

When we visited Mullardoch a weir to retain water for fishing in the river downstream of the dam had already been built by this method, an experimental slot had been filled, and tests were in progress on Colcrete specimens. We understand that the 28 day strength on an unrestrained compression test of a 6 in. test cube made with 2¼-1½ in. local aggregate and a 1 : 2 mix having a 0·58 water : cement ratio was 4,350 lb. per sq. in. A similar cube of plain grout and Logans sand yielded at 4,900 lb. per sq. in. Bond-stress test values were nearly 300 lb. per sq. in.

The method proposed to concrete the slots in the dam is to fill them with 3-2½ in. aggregate and to grout the two slots in each block in a single pour, the speed of the pour being regulated so that the lower levels begin to set before the pour is completed, ensuring that no part of the structure is subjected to undue hydrostatic head.

(To be continued)

Batching Plant for Whakamaru Dam

Winget Limited have completed a high-capacity fully automatic concrete batching and mixing station for this important New Zealand development. As an urgent export order the plant has been built to an extremely close delivery schedule

WE recently inspected at the works of Winget Limited, Rochester, England, a high-capacity fully automatic concrete weigh-batching and mixing station destined for the construction of the Whakamaru dam on the Waikato river, North Island, New Zealand. Whakamaru is the fourth of a chain of ten stations planned by the State Hydro-Electric Department, and will ultimately have a capacity of 100,000 kW.

The concrete plant is noteworthy not only because of its size and advanced design but because it has been built to an extremely close time schedule. The rapidly increasing demand for power in New Zealand gives the utmost urgency to these hydro-electric developments, and the original Winget quotation for 15 months delivery for the plant was met with an emphatic request for closer timing. In response to this, Winget Limited accepted liability for delivery ex works within eight months, and the plant was completed in advance of schedule. The event was signalised by a visit to the Winget works of His Excellency F. W. Doidge, the High Commissioner for New Zealand.

The general layout of the plant is shown in the perspective sketch, Fig. 1. A multi-compartment storage bin surmounts the structure and supplies a nest of automatic weigh batchers on a staging immediately below. These batchers can feed either of two mixers on a reinforced-concrete platform forming the first storey of the station, and these mixers discharge to a system of radial belt conveyors at ground level. When finally erected the plant will stand 75 ft. high and will occupy a ground area of 40 ft. by 50 ft.

The storage bin (Fig. 2) has a capacity of 400 cu. yards, and has six aggregate compartments arranged round a central cylindrical storage tank divided into two compartments, one for cement and the other for pozzolan. All compartments have steep sides to prevent hang-up and to avoid dead storage space. Aggregates are fed to the bin by a bulk conveyor and thence through a battery of vibrating screening units located above the bin into the various compartments by means of chutes. Cement and pozzolan are fed by screw conveyor to the central compartments. The discharge from the various compartments is controlled by pneumatically operated gates.

On the batcher level there are five aggregate batchers, one cobble batcher, one cement batcher, one pozzolan batcher and one water weigh batcher. All these batchers are scale mounted, and the weighing is carried out automatically in two stages—a rapid fill until the required weight is nearly attained, followed by the intermittent addition of small quantities to get accurate final weight. In Fig. 2 some of the batching hoppers will be seen arranged round the main storage bin; they have been inverted to clear the pneumatically operated discharge gates.

A view of the mixers is given in Fig. 4. They are of the Winget-Koehring type, each of 3 cu. yard capacity, and are tilted pneumatically. A two-way retractable feed chute receives the charges via a collecting cone from the batchers above. It is mechanically operated by the mixers themselves, and a dust-tight seal between the charging chute and the mixer mouth is made by a rubber sealing ring.

The entire station is operated by one man from a central control board, depicted in Fig. 3. The scale arm of each batcher is extended to this board to indicate the weight on a dial and to record it on a paper chart. A single chart accepts the records from all the nine batchers and is also marked with the date and time, so that a permanent record is made of every mix passed through the plant. Setscrew turrets above the dials enable any desired mix to be preset, and a selector knob allows any of 12 mixes to be selected instantaneously. Compensating gear is also provided to allow for variations in the moisture content in the sand.

On the desk of the control board is a series of

Fig. 1. Perspective sketch of the Whakamaru batching plant

Fig. 2. The multi-compartment 400 cu. yard storage bin and weigh batchers

Fig. 3. Central control board, incorporating dials and recorder pens for the weigh batchers and control switches for the entire plant

pushbuttons and indicator lights whereby each batcher can be charged and discharged. Further pushbuttons select the mixer it is desired to use and control the operations of charging, running and discharging it. All operations are checked by indicator lights, and a timer ensures that the mixer runs for a predetermined time before it can be discharged. An ammeter in each mixer-motor circuit indicates whether the mixer is operating full or empty.

Each set of pushbuttons has associated with it a changeover switch for hand or automatic operation. In the "hand" position the operation concerned has to be controlled by pushbutton; when all the switches are set to "automatic" the entire batching, mixing and discharging cycle proceeds automatically under the

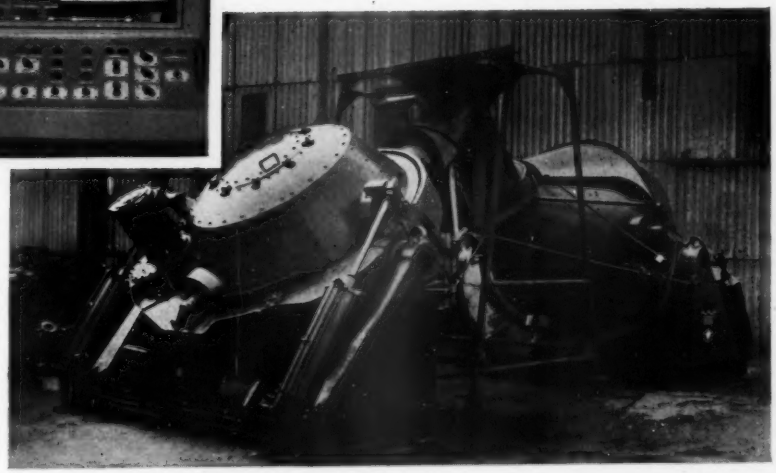


Fig. 4. The two 3 cu. yard Winget - Koehring mixers assembled with their feed chute

control of a motor-driven camshaft-type cycle controller.

All the control-board mechanism is housed in a dustproof glass-fronted case which is pressurised by a small motor-driven blower.

Plants of this type have been supplied for dam construction on many other important hydro-electric developments, including Owen Falls dam, Uganda; Grimsel and Oberaar dams, Switzerland; Venda Nova dam, Portugal; Barrage les Tignes, France; Hirakud dam, India; and for a new dam under construction by the Tasmanian Hydro-Electric Commission for the Trevallyn power development to serve the Tasmanian aluminium industry.

Abstracts from the World Technical Press

Tiber Valley Development

The following abstract is restricted to points not covered by the article printed in the February issue of WATER POWER, p. 44, and deals mainly with the civil engineering aspects of this project. The present Tiber Development Scheme is the logical outcome of investigations, initiated many years ago, which, at the outset, were carried out with a view to regularising the lower and middle stretches of the river for irrigation purposes. Once completed, this scheme, with its 15 power stations and eight storage reservoirs, will ensure a production of about 950 million kWh backed by a reserve of about 900 million kWh, as well as the irrigation of an area of no less than about 200,000 acres. In addition the river will become navigable as far as its confluence with the Nera, about three miles south-east of Orte.

The first construction stage comprises the Baschi reservoir and station, and the three low-head plants on the Tiber proper: Castel Giubileao, already in

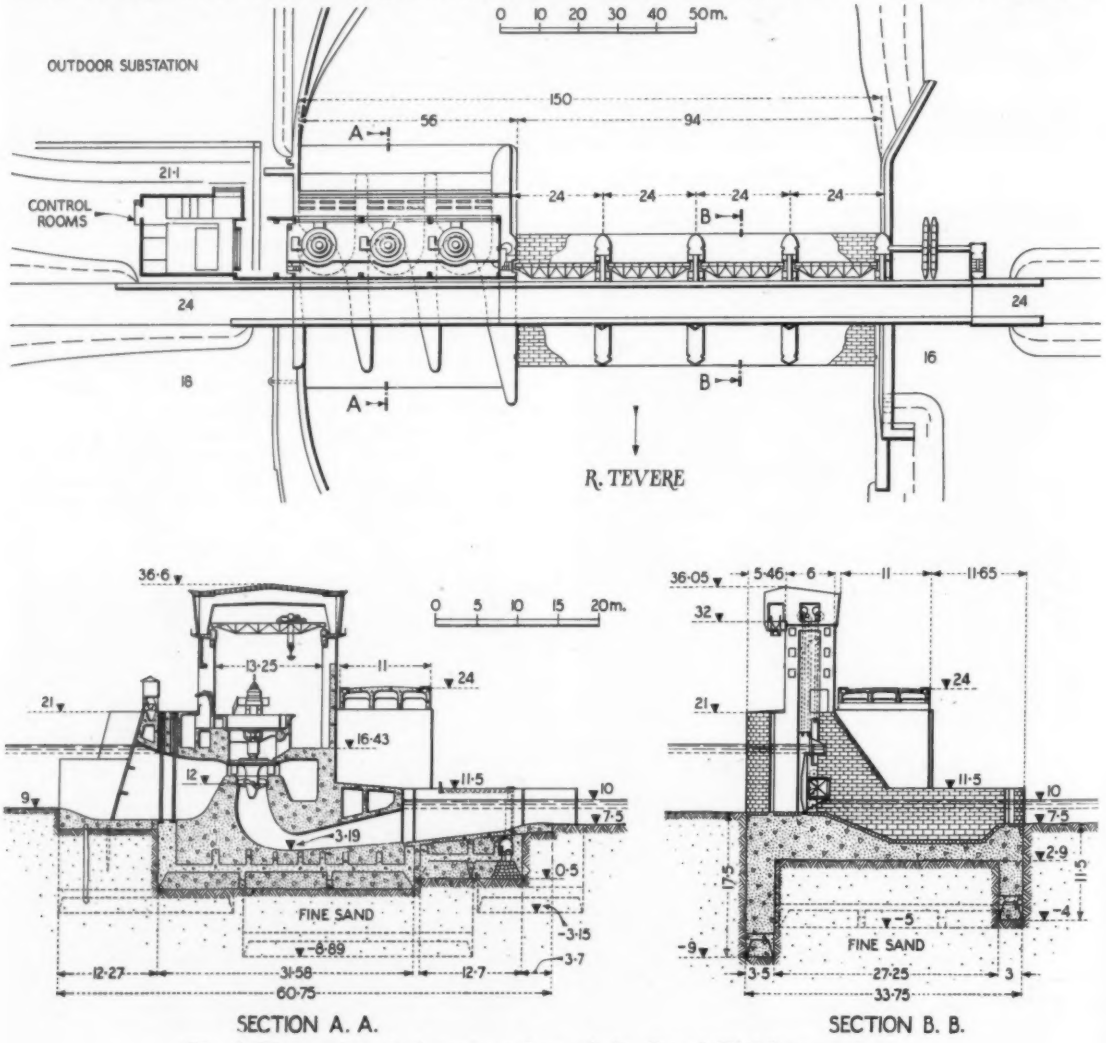
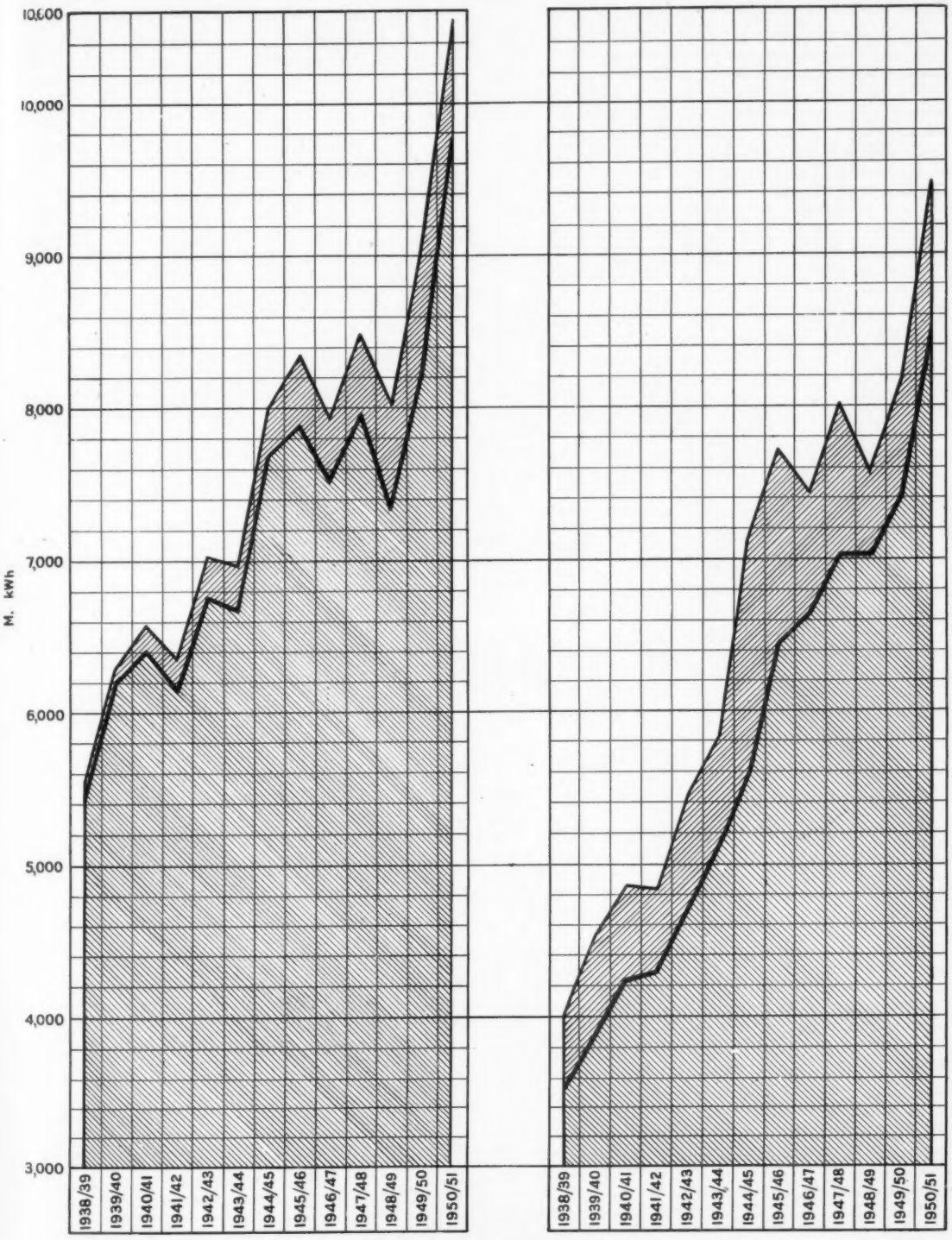


Fig. 1. Plan and typical cross-sections of the Castel Giubileao station



Electricity Supply in Switzerland

Fig. 1. Electric energy produced and supplied by public-utility concerns. Upper curve: *Total production inclusive of railway and industrial power plants, as well as imports.* Lower curve: *Hydro-electric production*

Fig. 2. Swiss consumption of energy. Upper curve: *Home consumption, including electric boilers and storage pumps.* Lower curve: *Home consumption, exclusive of electric boilers and storage pumps*

operation, Nazzano, now in course of completion, and Foglia

Fig. 1 shows the Castel Giubileao station in plan, and also reproduces typical cross-sections of the power-house proper and the dam respectively. The use of cofferdams sunk into the bed of the river was unavoidable to ensure perfectly safe foundations, since the river bed at the dam site consists mostly of fine sand. Excavation work began in January 1948; the lifting gear of the sluice gates, housed in the piers of the dam, was fitted in February 1950, the internal equipment of the power house and the outdoor substation followed in May and September 1950 respectively.

The setting up of the Castel Giubileao Station involved the following work:—

Open excavations	219,470 cu. yards
Compressed-air excavation	61,800 cu. yards
Volume of concrete, foundations included	106,500 cu. yards
Reinforcing steel	1,667 tons
Number of working days	350,000
Aggregate consumption of electric energy with work in progress ...	2,450,000 kWh

The Castel Giubileo station feeds three high-tension transmission lines connecting with the Nazzano plant, the State Railway system, and the distribution system of the Romana concern. (*L'Energia Elettrica*, Milano, Vol. 28, No. 12, December 1951, p. 714, 7 pp., 9 ff.)

Electricity Supply in Switzerland

The introduction to this survey contains sharp criticisms of the policy followed by some leading hydro-electric concerns in Switzerland with regard to public requirements. Owing to lack of understanding and co-operation, the Swiss hydro-electric power industry appears to have failed to avail itself to the full of the obvious goodwill shown by the public. The position was made worse by wrong anticipations as to the future development of energy consumption. It seems that during the period of industrial standardisation which preceded the Korea conflict, certain experts took a rather pessimistic view about constructing new hydro-electric plants while, in other quarters, fears were expressed that energy requirements could not be met during the winter months. The author attempts to refute these views by means of graphs based on the official statistics.

Fig. 1 displays the evolution of Swiss hydro-electric production, taken as a whole, during the last thirteen hydro-graphical years, each covering the twelve months' period from October 1 to September 30. The total increase of 4,400 M kWh represents an average yearly increase of about 330 M. This comparison shows clearly the gigantic effort made during the last ten years by the Swiss hydro-electric power industry in the utilisation of the water-power resources of the country. The curve above the production curve represents the total production inclusive of railways and private industrial concerns, thermal production, and imported energy. The narrow strip between the two curves corresponds to a supply of energy, varying between three and at most ten per cent., which public utility concerns could not draw from their own hydro-electric plants.

The consumption curves are shown in Fig. 2. Compared with the last pre-war year 1938-39, consumption during the 13 years instanced, exclusive of electric boilers and storage pumps, expressed in round figures, increased by 5,000 M kWh, while the hydro-electric power production of home plants did not exceed 4,300 M kWh. Taking the requirements of electric boilers and storage pumping plants into account, this increase amounts to about 5,450 kWh, *i.e.* a yearly average of 420 M kWh, which corresponds to the average possible production of the Verbois plant on the Rhone.

Further graphs show consumptions for the most important groups of consumers, *viz.* households and small trades, railways, industry, exports, etc.

As to the period following 1952, there is no reason whatsoever for anxiety. Not to mention several important projects either under consideration or approaching the construction stage, work is now in progress on no fewer than twelve large-scale plants with an aggregate production of 900,000 kW, ensuring about 1,800 M kWh in the winter, and about 1,400 kWh in the summer months. At the same time, these plants will raise the total storage capacity from 1,100 to 2,300 M kWh. (*Technische Rundschau*, Bern, No. 50, Vol. 43, 14.9.51, Section V, p. 33, 3 pp., 9 ff.)

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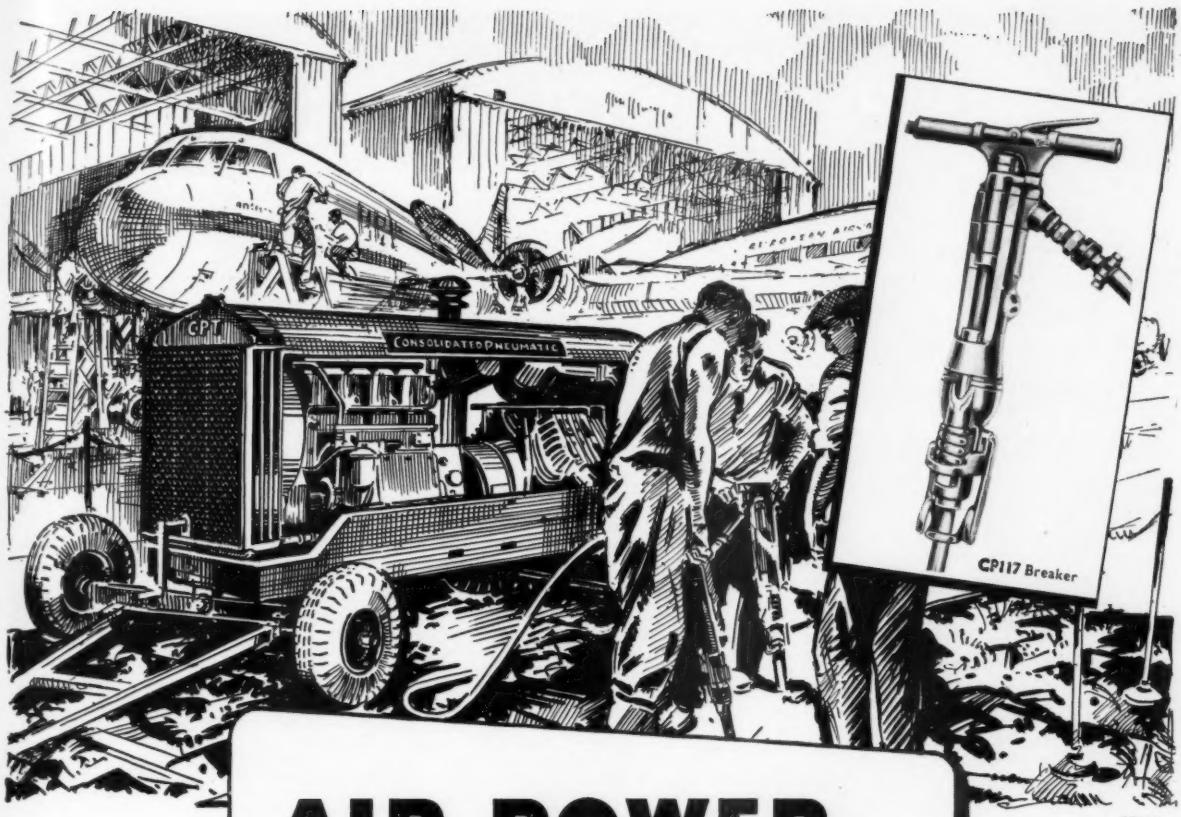

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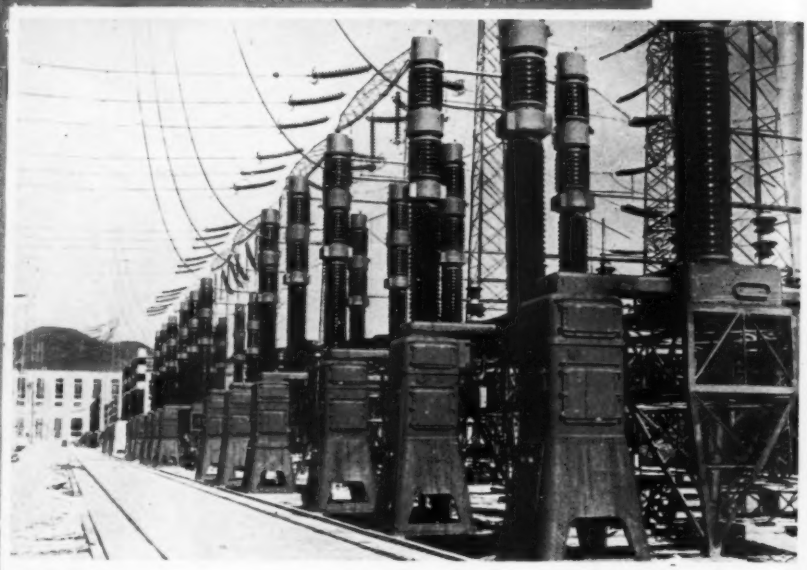

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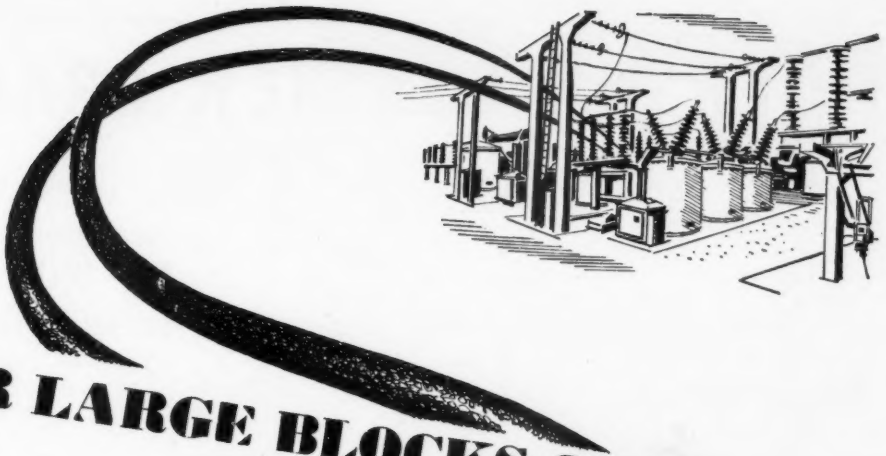

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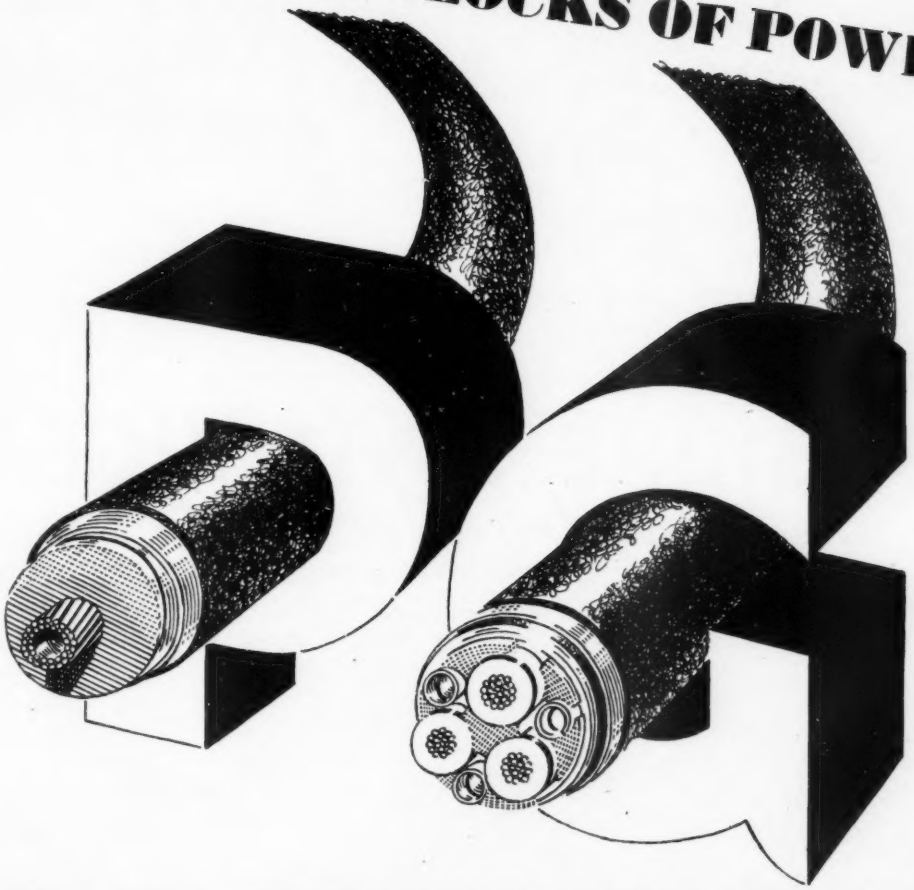

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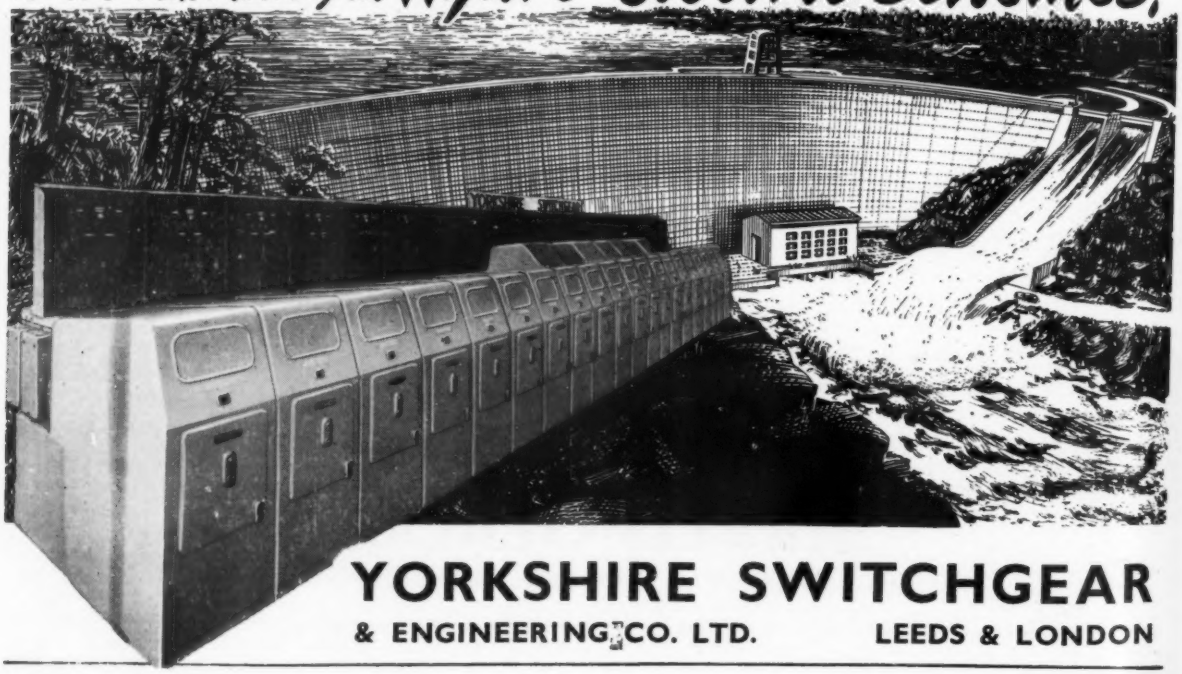

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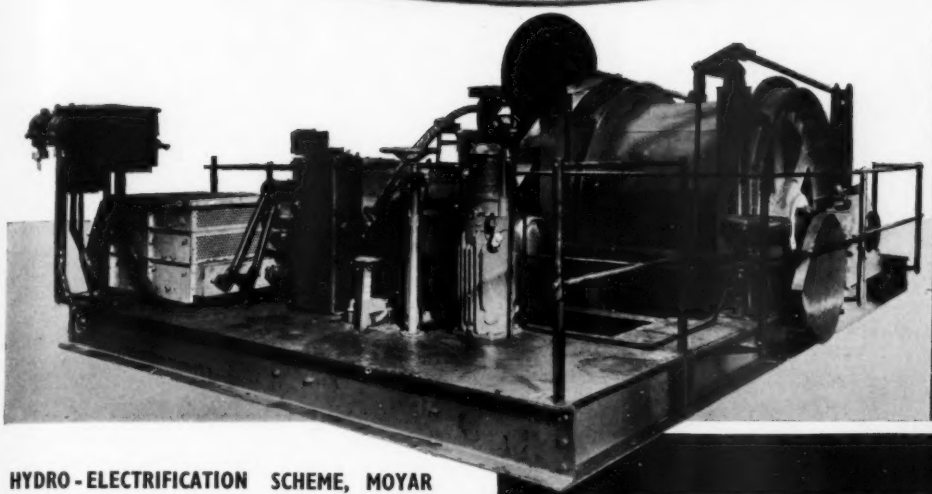

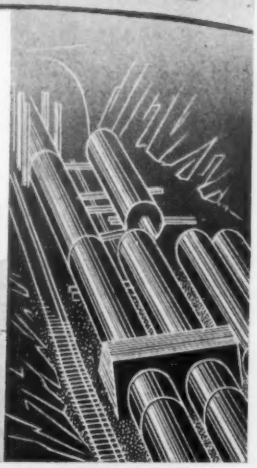

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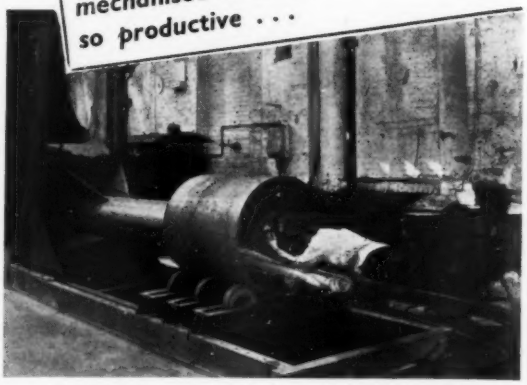

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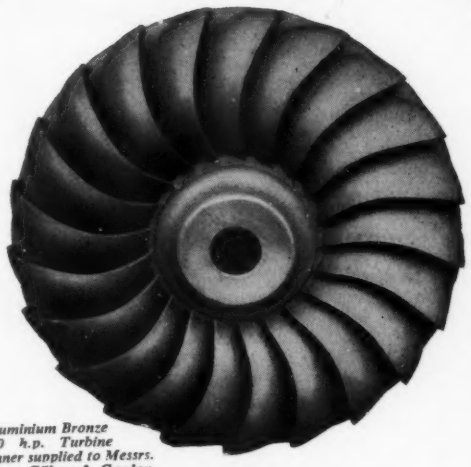
by

DR. P. W. SEEWER

Consultant and late Chief Engineer The English Electric Company Ltd.

Syllabus from Deputy Registrar, City & Guilds College



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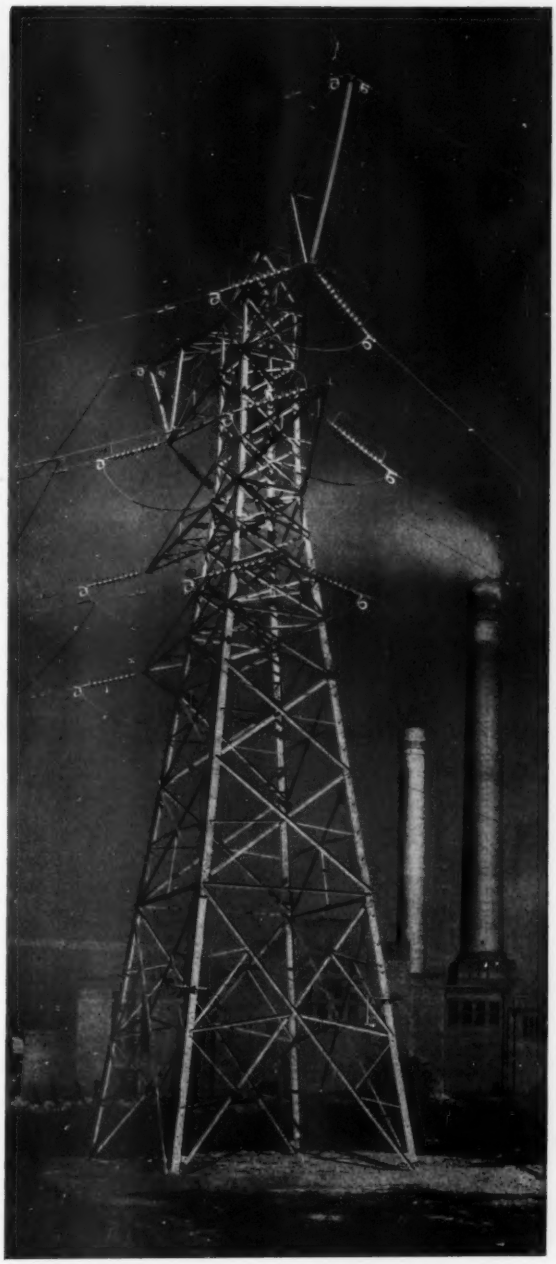

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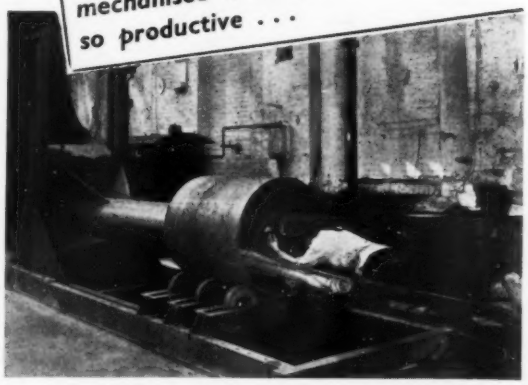

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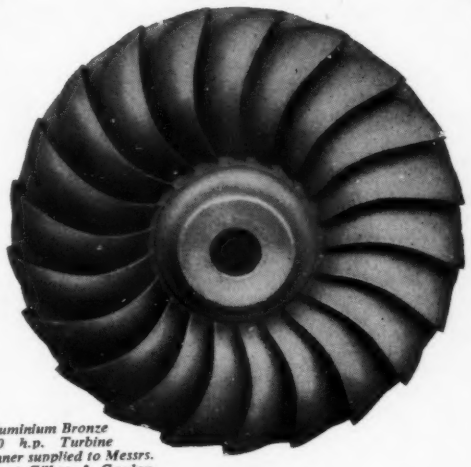

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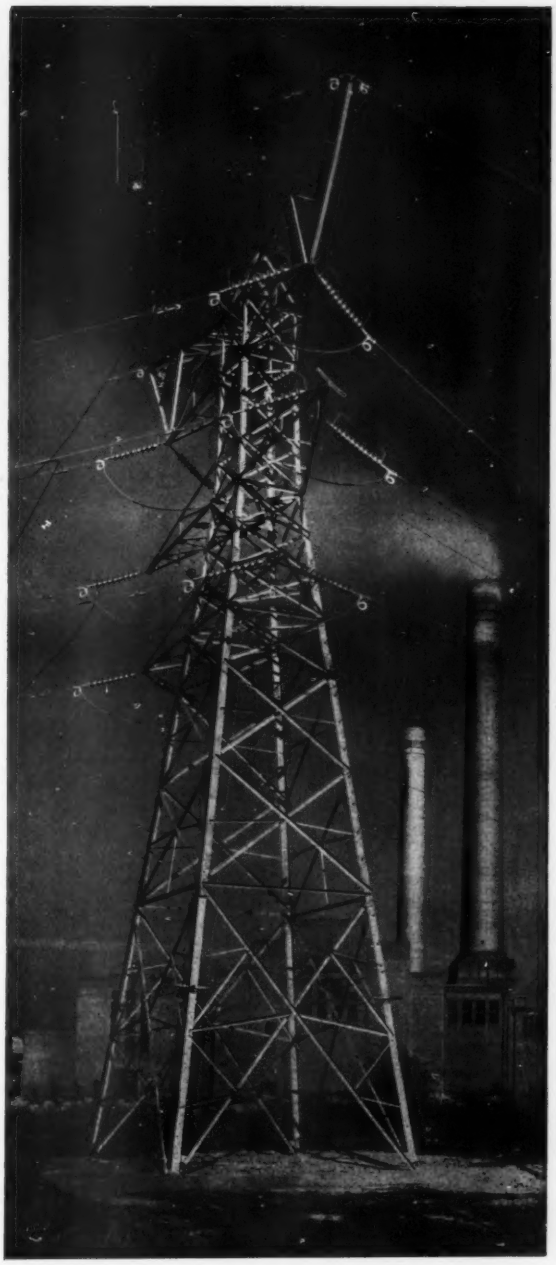

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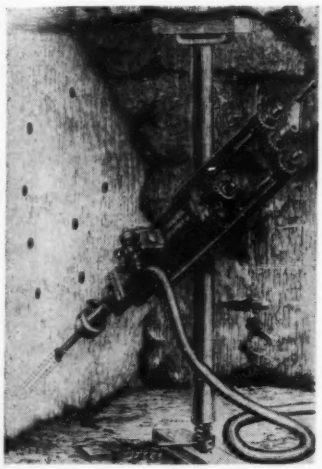

Early Holman Rock-Drill — Catalogue of 1881.

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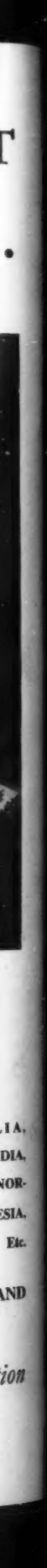
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